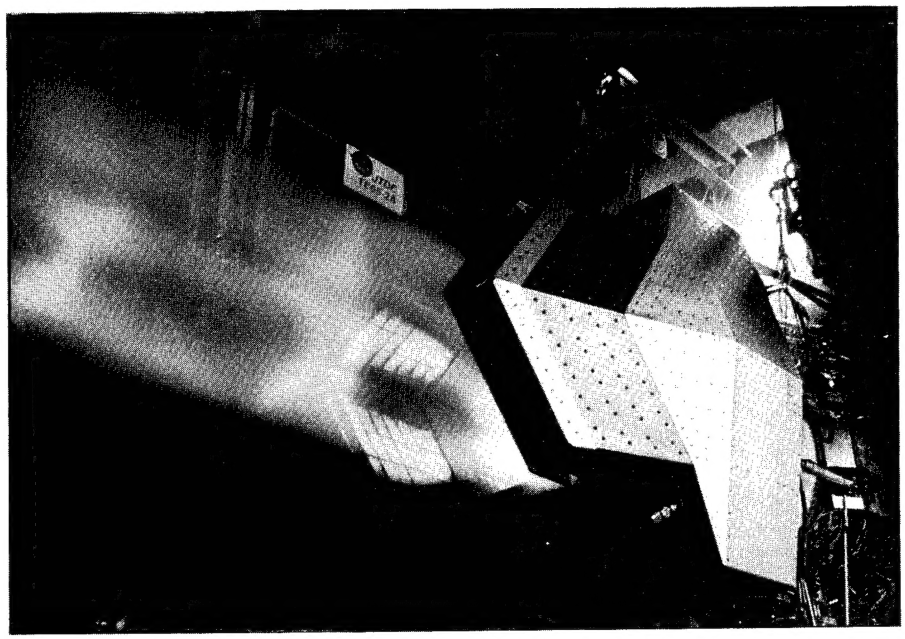
WL-TR-96-2000

FY96
Aero Propulsion & Power Technology Area Plan



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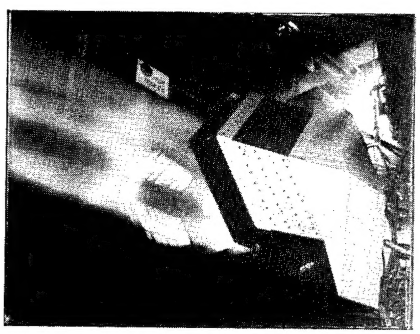
Note: This Technology Area Plan (TAP) is a planning document for the FY96-02 S&T program and is based on the President's FY96 Budget Request. It does not reflect the FY96 Congressional appropriations and FY96-02 budget actions, that may impact the S&T budget in selected TAPs. You should consult WL/XP, (513) 255-2622 for specific impacts that the FY96 appropriation may have had with regard to the contents of this particular TAP. This document is current as of 1 Aug 1995.



ON THE COVER

The Integrated High Performance Turbine Engine Technology (IHPTET) final Phase I demonstrator engine successfully achieved the IHPTET goals. IHPTET, a Wright Laboratory premier technology program, is an integrated triservice/ARPA/NASA/industry initiative aimed at developing technology for more affordable, more durable, higher performance turbine engines for all DoD aircraft and cruise missiles.

July 1995

Final

FY96 Aero Propulsion and Power Technology Area Plan (TAP)

PR 9993
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WL-TR-96-2000

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None

The Aero Propulsion and Power Technology Area is responsible for developing air breathing propulsion and power technology for Air Force use. Besides developing new technologies, product centers are supported by helping acquire systems and providing expertise to help solve developmental problems. Current research and development includes aircraft gas turbine engines (components, gas generators, technology demonstrator engines, fuels and lubricants), missile propulsion, (solid fuel ramjets, ducted rockets, and small turbine engines), aircraft and missile power (electrical and mechanical power generation, conditioning and distribution, energy storage, and thermal management), and plasma physics. Work is conducted primarily under contract, although an aggressive in-house program exploits new opportunities, maintains technical expertise, and verifies contractor findings. Supporting this are two dozen major in-house R&D facilities and an annual budget of over $150 million.

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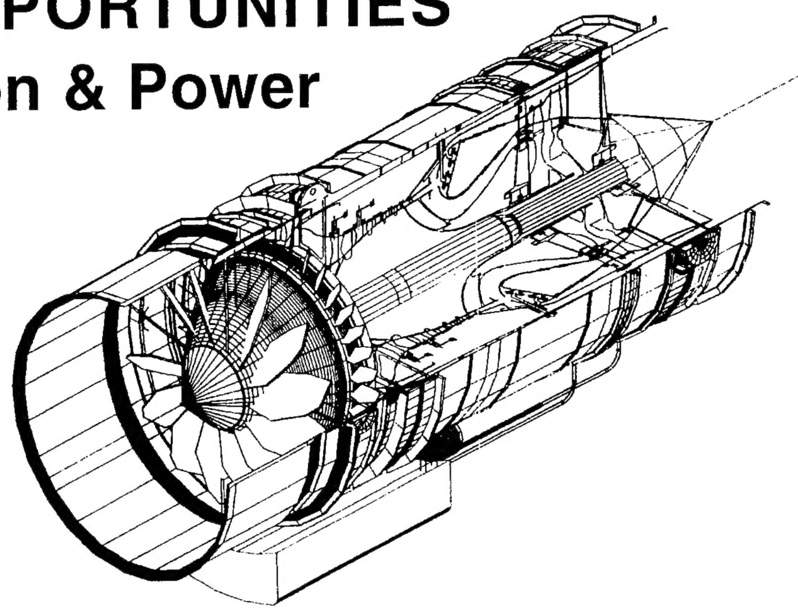
VISIONS & OPPORTUNITIES
Aero Propulsion & Power



The Integrated High Performance Turbine Engine Technology (IHPTET) initiative is revolutionizing propulsion capability

Wright Laboratory Aero Propulsion and Power technology area is the principal force in military air breathing propulsion and power, leading the nation's R&D effort for over 33 years. Under DoD guidance, we expect this Air Force leadership to expand, making contributions to all military services and the commercial sectors.

Most U.S. military and commercial systems, and many foreign systems as well, benefit from our research and development. Contributions range from the introduction of the high bypass ratio turbofan engine, that subsequently made wide-body transports possible, to the maintenance free battery used in today's aircraft. We are Air Force people who will continue this heritage, advancing technology to maintain and build the world's most respected air and space force – providing global power and reach for America.

Despite many advances since the dawn of the jet age, the potential of turbopropulsion has been only partially realized. By around the turn of the century, we expect this potential in terms of propulsion capability to be doubled relative to a 1988 engine technology baseline. This is due to the Integrated High Performance Turbine Engine Technology (IHPTET) initiative. Started within DoD – with support from Advanced Research Projects Agency (ARPA), National Aeronautics and Space Administration (NASA), and industry – this effort focuses the nation's R&D resources to provide dramatic increases in engine affordability, durability, and performance. IHPTET is structured to meet emerging turbopropulsion needs – current and future, military and commercial, for both aircraft and missiles. IHPTET enables:

- Upgraded and derivative engines – to enhance durability, performance, life, and survivability – that will lower cost of ownership and increase force effectiveness.

- New engines – with major emphasis on affordability – to improve durability, performance, life, and survivability that leads to revolutionary weapon system capabilities.

- Dual-use technologies – transferred from military applications – to improve commercial, industrial, and marine turbine engines.

New high speed air breathing missile propulsion concepts will revolutionize air combat, while maintaining the supportability characteristics of traditional rockets. Air-to-ground missiles will benefit through increased stand-off range and reduced time-to-target improving both aircraft survivability and missile kill probability. Air-to-air missiles will have increased launch ranges and expanded no-escape zones improving aircraft exchange ratio several-fold.

The capability for sustained flight up to and beyond Mach 5 for both military and commercial applications will be achieved. Combined-cycle engines – using storable hydrocarbon fuels – will be used for manned aircraft and dual-mode ramjet engines will be used for missiles and high speed aircraft. These developments offer:

- Global, time-urgent strike and reconnaissance aircraft that can operate from existing airfields and

have spin-off technologies applicable to high speed commercial transports.

- First stage propulsion for future military and commercial launch vehicles – that enables increased payloads and hence, more affordable access to space.

- High speed missiles, that use storable fuels, to rapidly attack time critical targets from long and inherently safe stand-off ranges.

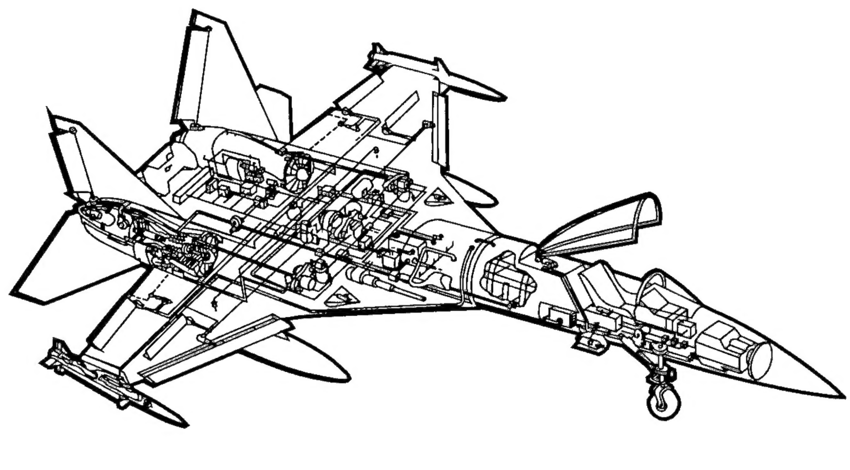
Fuels and lubrication will continue to be the "life blood" of gas turbines. Circulation of these fluids for aircraft thermal management will maintain the health and integrity of all systems. Future capabilities will include:

- A single, affordable high temperature capable jet fuel that eliminates fuel system deposits and related maintenance. This fuel will be applicable to both air and ground vehicles operating throughout all engine cycle temperatures and air vehicle speeds.

- Improved combustors that operate at high temperatures while reducing fuel consumption and pollution.

- Lubrication systems with fewer parts that weigh 50% less than existing systems. Included will be alternative nonlubricated mechanical components – such as magnetic bearings.

An essential feature of today's and tomorrow's systems is power. Our vision in this area is found in the More Electric Aircraft (MEA).



MEA is focused on aircraft internal power systems

This initiative is focusing technology developments of the services, NASA, and industry for the entire range of aircraft power components. Already underway, these developments will provide substantial benefits to both the Air Force and the nation:

- Power-by-wire that allows substantial reduction in aerospace ground support equipment and more than doubles reliability for aircraft power systems.

- Utilization of MEA technologies that offer an additional 11% sortie rate for a typical wing of F-16s over a 30-day war.

- MEA technologies that transition to the operational fleet to extend the life of the aircraft and to reap improved reliability, maintainability, and supportability (RM&S).

These visions give some idea of the breadth of work in the Aero Propulsion and Power technology area. The program benefits all aspects of Air Force operations by providing balanced improvements in affordability, performance, and supportability. Most of the technologies will continue to be adopted by the other services and the civilian sector, as they have been for decades.

This plan has been reviewed by all Air Force laboratory commanders/directors and reflects integrated Air Force technology planning. We request Air Force Acquisition Executive approval of the plan.

RICHARD R. PAUL
Brigadier General, USAF
Technology Executive Officer

DAVID A. HERRELKO, Colonel, USAF
Commander
Wright Laboratory

INTRODUCTION
Aero Propulsion & Power Technology Area Plan

BACKGROUND

Aero Propulsion and Power, highlighted in Figure I.1, is an integral part of the Air Force (AF) Science and Technology (S&T) program. It is also a key technology area contained in the Department of Defense (DoD) Technology Plan that describes the total DoD S&T effort. This DoD plan – as well as the Air Force program – is responsive to the S&T strategy issued by the Director of Defense Research and Engineering (DDR&E).

We play a major role in developing and executing Wright Laboratory's (WL) investment strategy. This strategy complements the DoD S&T plan. It is responsive to user needs, the changing defense budget, and an increasing need to develop more affordable, durable weapon systems. This strategy assumes buying fewer new systems and relying more on system upgrades using proven technological innovations.

Our technology area involves Research and Development (R&D) of turbine engines, fuels and lubricants, high speed propulsion, and power. This R&D provides the foundation necessary to maintain the competitiveness of both operational systems and those currently in development, while providing an increasingly capable technology base from which future systems can be developed with confidence.

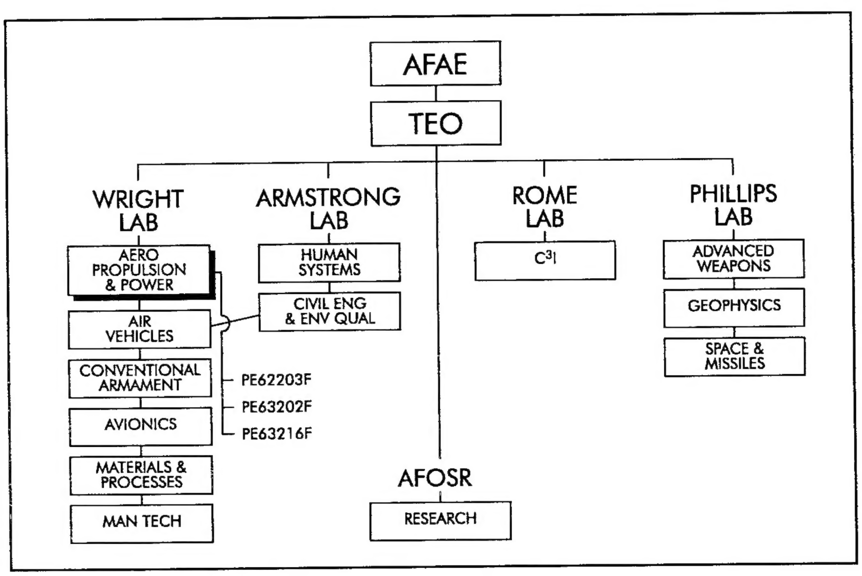


Figure I.1: Air Force S&T program structure

Propulsion and power technologies are common to all services. Most Army, Navy, and commercial engines are derivatives of Air Force power plants that we helped to conceive, develop, and/or demonstrate. Other services also use our developed fuels and lubricants. These numerous applications are primarily due to proven, practical technologies being available and affordable when needed by the users.

Joint programs are the most common business practice within this technology area. Examples include the Integrated High Performance Turbine Engine Technology (IHPTET) initiative, the More Electric Aircraft (MEA) initiative, and the evolving Wright Laboratory Hypersonic Technology (HyTech) initiative. All of these efforts successfully leverage precious resources to include people, facilities, and R&D dollars.

We make every attempt to be responsive to relevant user needs associated with both weapon systems and supporting infrastructure. These are articulated through the Technology Master Process (TMP) being implemented by Air Force Materiel Command. The TMP provides a comprehensive process for technology development, transition, and application/insertion having strong user endorsement.

This process is maturing quickly. The major commands have developed Mission Area Plans (MAPs) that document user mission "capability deficiencies." The Technical Planning Integrated Product Teams (TPIPTs) – led by the product centers with participation from laboratories, test centers, logistics centers, and major commands – are examining these deficiencies, roadmapping system

level solutions, and identifying the technology needs associated with the postulated system solutions or functions.

We primarily address weapon system technology needs found in the following TPIPTs:

- Air-to-Surface
- Counter Air
- Combat Search & Rescue
- Mobility
- Special Operations
- Reconnaissance/Surveillance/Intelligence
- Space Forces Support

The Aeronautical Systems Center for the Air Force Materiel Command has consolidated the recommendations of these and other TPIPTs in the Technology Investment Recommendation Report (TIRR). Needs currently supported by our technology area are listed in Table I.1. We are working daily with the TPIPTs to clarify these needs. This will ensure that we address the right set of technologies and make appropriate programmatic changes if warranted.

Infrastructure technology needs are being worked for both the test centers and air logistics centers. Specifically, turbine engine characteristics are being investigated for Arnold Engineering and Development Center and emergency power unit catalyst waste reduction methods are being evaluated for Ogden Air Logistics Center.

Accomplishments have been plentiful. During the past year, we met IHPTET's Phase I goals for turbofan/turbojet engines. These include 30% increase in thrust-to-weight ratio and 20% reduction in fuel burn. IHPTET Phase I is now complete and Phase II is well underway. We continue to work with our users to speed the transition of turbine cooling and exhaust nozzle technologies into current and future engine families. Finally, we continue to push the development of high temperature electronics providing smart actuators and control technologies to work in the hostile engine environment.

R&D successes are truly measured when the technology developed transitions to the operational world. The maintenance free battery program will successfully transition a maintenance free battery/charger system to the E-8 Joint Strategic Target and Recognition System (JSTARS). In addition to the battery program, development of a highly reliable 270-Vdc electrical power distribution system has been strongly endorsed by the F-22 System Program Office (SPO). Also, the C-17 SPO has strongly endorsed and is pursuing transition of an ultra-reliable air compressor for use with the aircraft onboard inert gas generation system.

The need for improved missile kinematic performance is being fulfilled by developing Variable Flow Ducted Rocket (VFDR) propulsion technology for advanced air-to-air missiles. Successfully demonstrated were a nozzleless booster at required temperature extremes, a ramburner with improved insulation, and a low smoke fuel.

In-house programs have made significant contributions to transitioning technology as well. Verified in our facilities were compressor low-aspect-ratio blading, high through flow technology, and swept blade aerodynamics. These concepts – now being adopted throughout the turbine engine industry – are leading to higher performance compression systems having fewer stages and parts resulting in lower costs and higher reliability. We have also begun initial testing of a further improvement to the swept blade aerodynamic concept – forward sweep – that promises even greater improvements in efficiency and operability.

F-22 customer support on fuel thermal stability and aircraft thermal management using JP-8+100 was provided through in-house efforts. Researchers are currently investigating a revolutionary

Table I.1: Consolidated list of needs

SELECTED TECHNOLOGY INVESTMENT RECOMMENDATION REPORT NEEDS

- Propulsion systems with high thrust-to-weight ratio
- Reduced observability signatures, IR, and acoustic
- Low observable turbofans
- Low observable propeller and rotor designs
- Expendable turbojet for unmanned vehicles
- Lower cost, more easily maintained turbine engines
- Dual-mode turbo ramjet
- Quick reaction to maximum range propulsion system for missiles
- Advanced fuel types
- Propellants for hypersonic missiles
- Improved power management and distribution
- Improved energy storage
- All electric auxiliary power unit (APU)

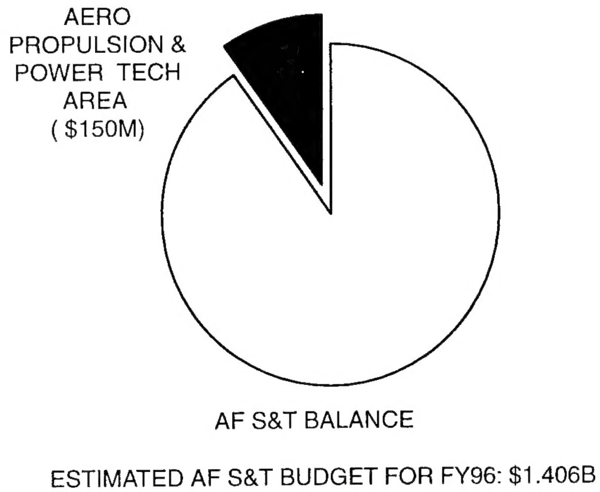


Figure I.2: Aero Propulsion & Power S&T funds vs. AF S&T funds

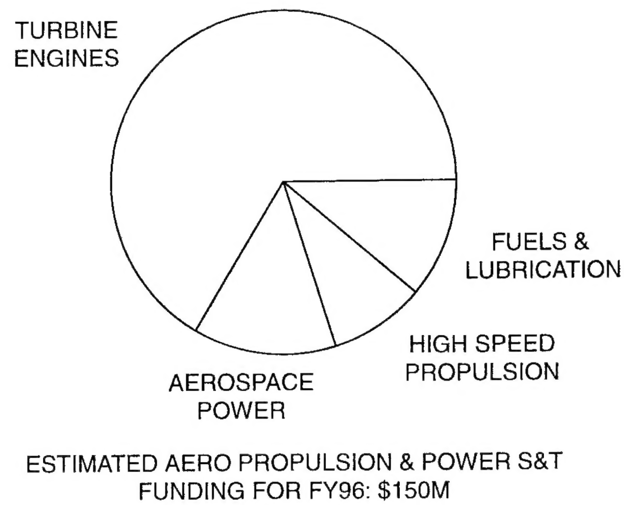


Figure I.3: Major technology thrusts

approach for flame stabilization with the trapped vortex combustor. New mechanical systems and a vapor phase lubrication system are the focus for advanced expendable engines. Other in-house testing documented catalytic heat exchanger performance that will enable hydrocarbon (JP type) fuels to be used for cooling high speed propulsion and vehicle structures.

Regarding funding, Figure I.2 shows the amount of money in the Air Force S&T program devoted to Aero Propulsion and Power. This funding along with program milestones are contained in the following Descriptive Summaries provided to Congress: PE62203F - Aerospace Propulsion, PE63202F - Aircraft Propulsion Subsystem Integration, and PE63216F - Aerospace and Propulsion Technology.

The funding supports our four thrusts listed in Table I.2. They were created to exploit new technologies, while maintaining a balance with user needs as expressed by the TPIPTs and documented in the associated TIRR. Figure I.3 shows how Air Force S&T funds – including payroll and operation costs – are apportioned across these thrusts.

Table I.2: Technology thrusts

THRUST NUMBER & TITLES
1. Turbine Engines
2. Fuels & Lubrication
3. High Speed Propulsion
4. Aerospace Power

Work in our technology area is augmented by a very active Small Business Innovation Research (SBIR) program. We currently fund over 40 active contracts valued at $8.2 million. The Air Force Office of Scientific Research (AFOSR) sponsors 10 basic research projects valued at about $5 million per fiscal year. This work is reported in the AFOSR Research Technology Area Plan (TAP). The Reliability & Maintainability Technology Insertion Program (RAMTIP) provides an additional $1 million to develop electric actuators and ceramic bearings. Discussed next are the objectives and contents of each thrust.

THRUST 1 provides the Air Force's (and most of the nation's) turbine engine technology base. Work is centered on the IHPTET initiative. This is DoD's highest priority effort in air breathing propulsion R&D. IHPTET encompasses the three services, ARPA, National Aeronautics and Space Administration (NASA), and the domestic turbine engine manufacturers. It offers breakthrough opportunities and is revolutionizing flight vehicle range, payload, agility, survivability, supportability, and affordability. A fully supported IHPTET initiative will ensure American dominance in this key technology area well into the next century.

THRUST 2 supports DoD user requirements with improved, environmentally acceptable fuels, combustors, lubricants, and lubrication systems. Thrust goals emphasize reducing both maintenance and waste in current systems while providing higher temperature capability to support current and future weapon systems. A far-term coal-derived fuel program is being pursued to assure national energy self-reliance. Being addressed are environmental concerns, fuel costs, and logistics. Much of this technology transitions directly to

operational systems with little or no additional development.

THRUST 3 focuses propulsion technology for high speed atmospheric flight undergirding Air Force doctrine of "Global Reach-Global Power." Manned vehicle propulsion efforts center on combined-cycle engines that draw on IHPTET for turbomachinery. Dual-mode ramjets are being developed for high speed missiles. These engine concepts use storable hydrocarbon fuels, enabling supportable and affordable sustained high speed flight for both military and commercial applications. Tactical missile propulsion needs are being addressed via the Variable Fuel Flow Ducted Rocket (VFDR) and ducted rocket technology development programs. These offer options for longer range, improved time-to-target, and increased no-escape zone.

THRUST 4 provides a common technology base from which power systems can be developed with confidence. The More Electric Aircraft initiative is a major work effort focused on air vehicles. Led by the Air Force, this initiative leverages support from the three services, NASA, and over 50 individual companies. Emphasis is on reducing the cost of force projection by doubling power system reliability and reducing our dependence on aircraft ground support equipment.

Thrusts 1, 2, and 4 also combine resources toward the demonstration of distributed electric engine controls, magnetic bearings, and internal starter/generators. These are enabling technologies supporting the achievement of IHPTET's and MEA's aggressive goals.

RELATIONSHIP TO OTHER TECHNOLOGY PROGRAMS

Aero Propulsion and Power is a broad-based area that deals primarily with energy and its transformation. As such, it is closely linked with most of the other Air Force technology areas. Foremost of these are Air Vehicles (engine/airframe integration, thermal management, aircraft subsystems), Conventional Armament (missile batteries and engines), Materials (engine materials and lubricants), Manufacturing Technology (producibility), Space and Missiles (missile power), Avionics (high temperature electronics), Advanced Weapons (high power technology), and the AFOSR Research technology area (compressors, heat transfer, combustion, plasma physics). This linkage has been extended to the other services and further documented under the DoD Technology Plan.

Turbine engine R&D, through IHPTET, is thoroughly integrated with that of other government organizations and with the nation's manufacturers. The area typically leverages slightly more than its annual funding through contractor Independent Research and Development (IR&D) efforts. IR&D is a major contributor in maintaining our technological superiority and is applied to both military and commercial products. These efforts provide aircraft engine enhancements that otherwise would not be available from DoD funds.

Joint planning activities for the More Electric Initiative have formed a strong coalition between the services and NASA. The Army now relies on the Air Force for all of its electrical power technology developments for aviation systems. Additionally, the Army and Air Force are teamed to insert more electric technologies into electric vehicles for tactical and nontactical applications. The Navy and Air Force are jointly developing advance power electronics for on-board ship power conditioning.

The Joint Aeronautical Commander's Group Joint Planning Team for the MEA continues to benefit from leveraging the nation's IR&D resources in electric subsystems and componentry. Funding in More Electric IR&D technologies exceed $20M per year across 50 participating companies.

Under Project Reliance, joint plans among the services have been developed to coordinate all research and development activities. Army fuels and lubricants researchers have collocated to share WL's research facilities.

All four thrusts have international ties with emphasis on those areas where we have the most to gain. Most important is high speed propulsion, an area that – because of its breakthrough potential – many other countries are aggressively pursuing. Congressionally earmarked funds (Nunn amendment) are supporting international programs to augment our ducted rocket efforts with higher energy propellants, simplicity, reliability, and reduced costs. Also, several international data exchange agreements exist to enhance our ramjet, ducted rocket, and combined-cycle engine concepts. These efforts help us to gain technical insight and to leverage limited R&D dollars.

In regard to the civilian sector, spin-offs will continue to be both common and important. A large portion of our developed technologies eventually wind up in commercial airplanes. Indeed, Air Force S&T is largely responsible for maintaining American dominance and a favorable balance of trade in this key field. This is also beneficial, in that the Air Force often buys "commercial" aircraft and engines for its airlift fleet.

CHANGES FROM LAST YEAR

Emphasis in our program continues to focus on a balance between the sometimes conflicting demands of performance, producibility, supportability, and affordability.

A significant change has been the expanded interest in solving durability issues – specifically, high cycle fatigue (HCF) in turbine engines. This issue has been raised to the highest levels within DoD and a "tiger team" involving members from DoD, industry, and academia has been formed to quantitatively define the challenge and identify/refocus necessary technology programs. Areas requiring improvement are unsteady aerodynamic prediction methods, damped mechanical response, and improved material capability and characterization. Also, instrumentation and test methods require attention.

We have placed higher priority on the transition of IHPTET and MEA technologies to multiple customers, both military and commercial. Of special note is the emergence of the Joint Advanced Strike Technology (JAST) program – that will further mature key propulsion and power technologies and system designs necessary to meet both Air Force and Navy next generation strike aircraft needs. IHPTET and MEA technologies and demonstrations are an important part of the foundation for the JAST program.

Programs continue to be structured to assure technology insertion into fielded systems. Examples include programs to develop technology upgrades for existing and developmental engines. Efforts are underway to develop propulsion technologies – both turbine engine and ramjet – for low cost smart weapons. Also, exploratory development has been bolstered to support alternative fuels research for the ducted rocket missile propulsion program.

Consortia between government/industry/academia are continually expanding. These consortia are cost effective partnerships to work common technical issues that require large resources of capital. The result is win-win for the participants and for the country.

Due to concerns regarding future fuel availability, Congress continues to mandate a program to develop high temperature, thermally stable and endothermic fuels from coal. Building on existing programs, the resulting cooperative effort between the Air Force and the Department of Energy reaches beyond immediate Air Force requirements to ensure future availability of all fuels well into the next century.

Congressionally mandated cuts to the FY95 budget have slowed development of the 270-Vdc electrical distribution system important to the F-22. This effort will continue as planned with anticipated full funding in FY96.

With the draw-down in defense, we have become more actively involved in forming partnerships with industry and academia. We are taking advantage of our in-house strengths to develop Cooperative Research and Development Agreements (CRDAs) with nonfederal partners to enhance technology transfer. Neither the military nor commercial world can afford to fully fund all research and development efforts required to maintain our technological edge in the international market. However, since much of our technology has dual-use potential, we are able to leverage our resources with industry in order to develop technologies that benefit both military and commercial applications. This enables the nation to effectively compete in the international market.

SUMMARY

Our technology area plan describes a well-balanced program that:

- Is focused on user priorities,
- Is responsive to policy guidance,
- Exploits technological opportunities and revolutionary approaches, and
- Leverages budgets through extensive cooperation with other laboratories, agencies, and industry.

The chapters that follow highlight our four thrusts. Described are user needs found in the TIRR, goals, major accomplishments, changes from last year, and milestones. These chapters represent our strategy to meet the current and future needs for defense research and development.

PROGRAM DESCRIPTION

THRUST 1: TURBINE ENGINES

Affordable, durable, high performance engines

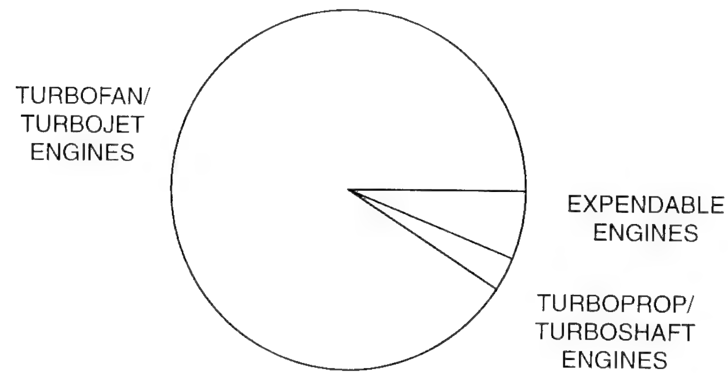


Figure 1.1: Turbine Engines subthrusts ($100.2M)

INTRODUCTION

Airbreathing propulsion is a DoD key technology that this thrust supports through the Integrated High Performance Turbine Engine Technology (IHPTET) initiative. IHPTET is a joint DoD/NASA/industry initiative focused on developing turbine engine technologies for more affordable, more durable, higher performance engines.

IHPTET is strongly supported by Congress and is often cited as the premier example of a coordinated government-industry technology development program. Air Force funding and subthrusts supporting a major part of this effort are indicated in Figure 1.1. It represents the largest investment in the Aero Propulsion & Power Technology Area.

Historically, propulsion technology has dramatically influenced the development of modern weapon systems. This is evident by the fact that the propulsion system (engines plus fuel) accounts for 40 to 60 percent of the aircraft takeoff weight and for 20 to 40 percent of the total weapon system life cycle cost (LCC). Also, aircraft-related expenditures account for approximately one-third of the total DoD budget. Considering these facts, it becomes obvious that achievement of the IHPTET goals will significantly enhance future military aircraft capability and provide for more affordable weapon systems.

"Two things I look for in engines these days – are cost of ownership and more robust durability. And I applaud IHPTET for taking those on as major goals in the IHPTET initiative."

– Gen John M. "Mike" Loh
Commander, Air Combat Command
October 3, 1994

Aircraft gas turbine technology is also vital to the U.S. industrial base. The value of military and commercial shipments for the domestic aircraft gas turbine manufacturers was approximately $22.3 billion in 1993, split about equally between each. Further, by virtue of the aircraft gas turbine importance

in determining the overall quality of aircraft, turbine engines are a major factor in the current favorable balance of trade in the aerospace sector. Because aircraft gas turbine technology is largely applicable to both military and civil engines, achieving the IHPTET goals can ensure continued U.S. preeminence in the increasingly competitive international turbine engine marketplace well into the 21st century.

In the short run, IHPTET contributes to U.S. national security through enhanced weapon system capability – military superiority. In the long run, IHPTET contributes to U.S. national security by bolstering the industrial base – commercial preeminence.

Figure 1.2 outlines opportunities for step-wise technology transition for each class of turbine engines. The IHPTET goals are listed in the Goals section and are further explained in the DoD Aerospace Propulsion and Power Technology Plan.

USER NEEDS

This thrust, and indeed the entire IHPTET community, use the Integrated Product Team (IPT) approach to ensure development of usable turbine engine technology. The IHPTET IPTs have developed integrated/coordinated plans through the year 2003 to achieve the challenging IHPTET goals. These IHPTET plans allow sufficient latitude to accelerate the demonstration and transition of higher priority technologies in response to nearer-term Air Force needs while at the same time providing longer-range focus on our vision of doubling propulsion capability.

Today, the IHPTET technology transition process is being enhanced via the Technology Master Process (TMP) – as discussed on page 29. Outputs of weapon system user needs are defined in various Mission Area

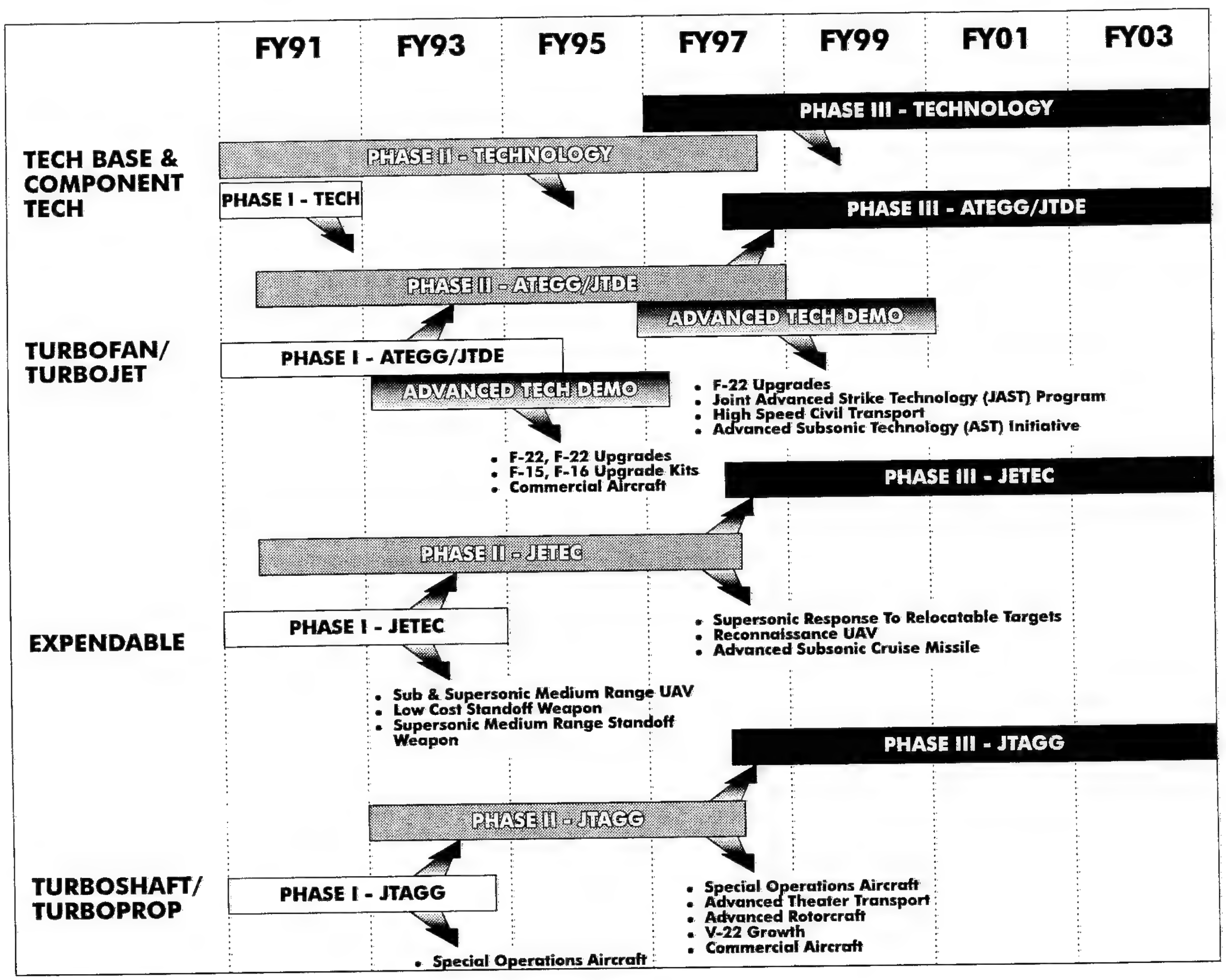


Figure 1.2: Thrust 1 - Turbine Engines

Plans (MAPs). These are consolidated by the Aeronautical Systems Center (ASC) for the Air Force Materiel Command (AFMC) in the Technology Investment Recommendation Report (TIRR). This report provides unified guidance to laboratories, and thereby affords a basis for focusing laboratory thrusts – where appropriate – to address current and projected needs.

To date, many weapon system user needs involving turbine engine technology have been defined through this process and are summarized in Table 1.1. In all cases, the IHPTET initiative is positioned to deliver demonstrated technologies to the user through the aggressive technology development plan – thereby lowering the user's technology introduction risk.

The following illustrates how the user defined technology needs are being addressed:

- Improve durability of current and future engines – specifically high cycle fatigue (HCF) issues associated with titanium components.
  - Eliminate/reduce one of the largest causes of fleet "stan-down," and
  - Avoid expensive mid-life design changes by designing robustness into components from the outset.
- Provide supersonic engine technologies with minimum cross section, low weight, increased thrust, reduced acquisition cost, and low cost of ownership for the Joint Advanced Strike Technology (JAST) defined by DoD.
- Develop a "distributed control system" in which engine accessories are located where they are needed and we "pump electrons" instead of hydraulic fluid, oil, or fuel – often relying on high temperature silicon carbide. Fundamental electrical technologies are described in Thrust 4, Aerospace Power and also in the Avionics Technology Area Plan (TAP).
  - Dramatically improves the reliability and maintainability of our engines – a prime user concern.
  - Eliminates the need for on-engine hydraulic systems, gearboxes, all associated plumbing, and some unique flightline specialists.
- Develop internal engine starter/generator technology.
  - Eliminates the central hydraulic unit, the power takeoff shaft (the "umbilical cord" between the engine and aircraft), and the gearbox that are another major source of maintenance actions.
- Address noise level requirements that can place military transports and helicopter platforms at risk from an observability standpoint. Technologies such as swept

Table 1.1 : Consolidated list of needs and MAP reference

USER DEFINED TECHNOLOGY NEEDS	USING COMMAND & MAP
• Increased range, payload, and maneuverability	ACC: Counter Air, Air-to-Surface SOC: Joint Air Battlefield, Combat Support, Force Application, Psychological Ops
• Next attack aircraft	ACC: Counter Air, Air-to-Surface SOC: Joint Air Battlefield, Combat Support
• Low cost, LO subsonic stand-off weapons	ACC: Air-to-Surface
• Built-in-test, fault isolation	ACC: Air-to-Surface
• Design for two-level maintenance	ACC: Air-to-Surface
• Rapid response weapon capability	ACC: Counter Air, Air-to-Surface
• Increased reliability, maintainability, and supportability (RM&S) for AMC aircraft	ACC: Counter Air, Air-to-Surface AMC: Airlift, Air Refueling
• Power/propulsion noise reduction	AMC: Airlift, Air Refueling SOC: Force Application, Joint Air Battlefield, Combat Support
• Reduce signature of SOF, attack, and fighter aircraft	SOC: Combat Support, Joint Air Battlefield, Force Application ACC: Counter Air, Air-to-Surface

ACC: Air Combat Command SOC: Special Operations Command AMC: Air Mobility Command

aerodynamics and variable cycle engine concepts all contribute to this effort.

- Provide the IHPTET core engine base for the Advanced Subsonic Technology (AST) and High Speed Research (HSR) programs – two premier U.S. investments by NASA that are part of the national/civil sector aircraft gas turbine technology development plan currently being defined by DoD, NASA, and industry.

- Support infrastructure technology needs for the Arnold Engineering and Development Center. Specifically, turbine engine observables and component dynamics are being characterized to provide enhanced test and simulation techniques.

Nearly all of the nearer-term user needs identified "reduced engine acquisition cost and reduced cost of ownership" as a fundamental need along with increased durability, repairability, maintainability, supportability, and performance (increased thrust-to-weight and lower fuel consumption). To increase attention on cost reduction issues, programs under this thrust have been structured to integrate IHPTET designs with advanced manufacturing processes to reduce all aspects of cost for new, derivative, and upgrade engines. Methods for cost reduction through advanced technology are:

- Dual-use: use the same technology twice.

  - "Common engine cores" can be used in a wide range of applications from multiple fighter engines, to high bypass-ratio engines for military and commercial transports, to industrial and marine engines. Over 75% of the DoD turbine engine investments are applicable to civil sector needs.

- Tailor the engine performance during flight – optimize for the mission point.

  - Variable cycle engine (VCE) concepts permit more efficient operation over a broader portion of the flight envelope. Specifically, use of VCE concepts should result in elimination of the augmentor with its attendant very high fuel usage and high signature, and the variable geometry exhaust nozzle with its high weight, complexity and cost. Our designs indicate that exhaust nozzle weight can be reduced by 80% and cost by 70%.

- Maximize design application of new knowledge.

  - "Swept aero" provides higher pressure ratio in fewer compressor stages, a 3-5% higher efficiency, and greatly increased ruggedness. It is also an excellent example of a dual-use technology. If applied across the U.S. military and civil aircraft fleets, swept aero designs would save $1 billion per year in fuel use alone. The first fan design with IHPTET derived swept aerodynamics is now in production in the FJ44, a commercial engine.

  - "Super-cooled" turbine blade designs permit 300°F higher gas temperature for increased thrust, or 30% reduction in blade cooling air for reduced fuel consumption, or 2- to 4-fold increase in turbine blade life – all at a reduced manufacturing cost. The potential for a $3 billion Air Force life cycle cost (LCC) savings by using "super cooling" in the F119 (F-22 engine), F100 (F-15, F-16 engine), and F110 (F-16 engine) has resulted in a strong "user pull." We are accelerating the transition of these technologies to meet near-term user needs.

  - Integrated low observable (LO) designs synergistically use advanced IHPTET technology to reduce the manufacturing cost, weight, and performance penalties associated with stealth. Addressing LO requirements up front using an IPT approach allows us to "build-in" rather than "bolt-on" stealth technologies, thus avoiding weight, cost, and maintainability problems.

In summary, all programs in this thrust are focused on meeting the IHPTET goals – improved engines lead to lower weapon system cost. Special emphasis is being placed on resolving durability issues and on reducing acquisition cost – in response to user requirements and guidance from DoD.

GOALS

Figure 1.3, next page, summarizes the technology development plan for the three classes of demonstrator engines:

- Large pilot-rated turbofan/turbojet engines for fighters, bombers, and transports;
- Smaller pilot-rated turboprop/turboshaft engines for trainers, rotory wing, subsonic patrol, special operations aircraft and theater transports; and
- Expendable engines for cruise missiles and unmanned air vehicles (UAVs).

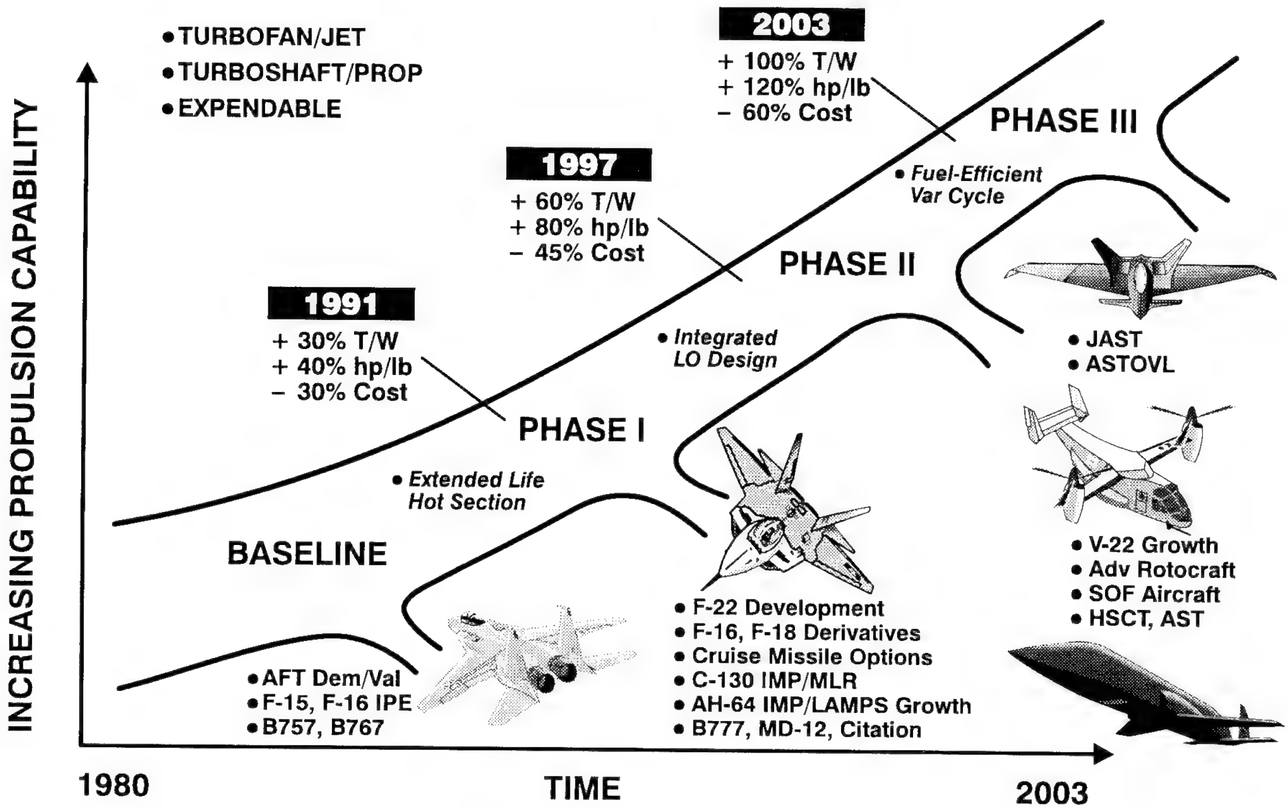


Figure 1.3: IHPTET technology development

The time-phased approach of the IHPTET initiative provides opportunity for near-term technology transition, reduces technical risk, and defines interim milestones against which progress is assessed.

The specific IHPTET goals are:

TURBOFAN / TURBOJET:
- Phase I (1991)
  - +30% thrust/weight
  - -20% fuel burn
  - $120/pound of thrust
  - $5.65/KEFH*/pound of thrust
- Phase II (1997)
  - +60% thrust/weight
  - -30% fuel burn
  - $95/pound of thrust
  - -20% $/KEFH*/pound of thrust
- Phase III (2003)
  - +100% thrust/weight
  - -40% fuel burn
  - $80/pound of thrust
  - -35% $/KEFH*/pound of thrust

TURBOSHAFT / TURBOPROP:
- Phase I (1991)
  - +40% power/weight
  - -20% SFC
- Phase II (1997)
  - +80% power/weight
  - -30% SFC
- Phase III (2003)
  - +120% power/weight
  - -40% SFC

EXPENDABLES:
- Phase I (1991)
  - +35% thrust/airflow
  - -20% SFC
  - -30% cost
- Phase II (1997)
  - +70% thrust/airflow
  - -30% SFC
  - -45% cost
- Phase III (2003)
  - +100% thrust/airflow
  - -40% SFC
  - -60% cost

*1000 engine flight hours

Examples of system level payoffs from achieving the challenging IHPTET goals include:

- Intercontinental range in an Air Launched Cruise Missile (ALCM)-sized missile,
- Five-fold increase in speed for tactical cruise missiles,
- A 100-percent increase in range/payload for both attack aircraft and helicopters with enhanced maneuverability,
- A sustained Mach 3+ capability in an F-15-sized aircraft,
- A 100 percent increase in unmanned aerial vehicle endurance, and
- Greater range/payload capability in an F-18-sized Short Takeoff/ Vertical Landing aircraft.

MAJOR ACCOMPLISHMENTS

Accomplishments have been plentiful. During the past year, we met IHPTET's Phase I goals for turbofan/turbojet engines. These include 30% increase in thrust-to-weight ratio and 20% reduction in fuel burn with no sacrifice in life or durability. IHPTET Phase I is now complete and Phase II is well underway.

Additional testing of key IHPTET technologies continued in dedicated structural/environmental advanced technology demonstrators. These durability "shakedowns" reduce the risk of technology introduction into future and current systems, lead to improved performance and capability, and ultimately result in significant LCC reductions. The payoffs for the F119 include system LCC savings of $420 million plus 10-20% thrust increase, 2-5% specific fuel consumption (SFC) decrease, and 15-20% cost and weight reduction for the augmentor and exhaust nozzle. For current engines, the payoffs include system LCC savings of over $1 billion plus doubled turbine life, reduced exhaust signatures, improved operability, and increased aircraft range.

The Government/Industry/University Forced Response Consortium, established to address high cycle fatigue (HCF) failures in fan and compressor blades, was expanded with a series of experiments in the WL Compressor Research Facility (CRF) to provide high quality research data for HCF analysis. This consortium was formed in response to a Scientific Advisory Board (SAB) recommendation.

The Air Logistics Center (ALC) engineer exchange program – with San Antonio and Oklahoma– allows us to better acquaint laboratory engineers with logistic center needs and their engineers with our technology programs. This has already resulted in improved communication and increased support of ALC needs. For example, the new compressor blade analysis program, "Blade GT," was modified to better respond to ALC needs. This low cost, user friendly program, which runs on a personal computer, will be used to assess foreign object damage (FOD) and component repair limits.

CHANGES FROM LAST YEAR

Our focus on achieving the challenging IHPTET goals is unwavering. Programmatic changes have occurred to further demonstrate IHPTET technologies in response to recently defined user needs.

The most profound change has been the renewed and expanded interest in solving durability issues – specifically, high cycle fatigue (HCF) in turbine engines. This issue has been raised to the highest levels within DoD and a "tiger team" involving members from DoD, industry, and academia has been formed to quantitatively define the challenge and identify/refocus necessary technology programs. Areas requiring improvement are unsteady aerodynamic prediction methods, damped mechanical response, and improved material capability and characterization. Also, instrumentation and test methods require attention.

The Air Force/Industry Affordability Working Group continued to accelerate efforts for reducing the acquisition, operation, and support costs of turbine engines. As a result of this group's recommendations, cost reduction goals for IHPTET were formally accepted. Acquisition cost reduction, measured in dollars per pound of thrust and maintenance cost reduction, measured in dollars per thousand engine flight hours per pound of thrust, are the two new goals.

Of special note is the emergence of the JAST program – that will further mature key propulsion technologies and propulsion system designs necessary to meet both Air Force and Navy next generation strike aircraft needs. IHPTET technologies and demonstrations supply the foundation of the JAST propulsion effort.

MILESTONES

Selected milestones towards achieving the IHPTET goals are:

- Core engine test of third generation supercooled turbine blades for longer life and increased performance – fourth quarter FY95,
- Feasability of fluidic control of exhaust area and thrust vectoring for reduced complexity/weight – first quarter FY96,
- Engine test of high temperature metal matric composite (MMC) disk compressor – fourth quarter FY97,
- Demonstrator test of advanced-Variable Cycle Engine (VCE) concept – first quarter FY98, and
- Engine test of full-up magnetic bearing system – third quarter FY01.

THRUST 2: FUELS & LUBRICATION

Develop the fuels and lubricants to satisfy all propulsion and air vehicle thermal management needs

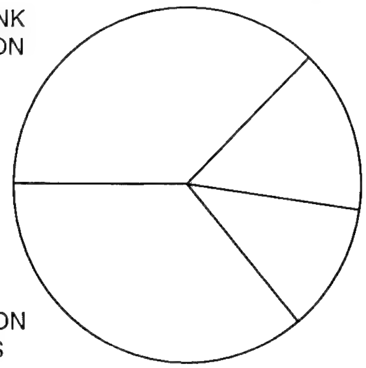


Figure 2.1: Fuels and Lubrication subthrusts ($16.6M)

INTRODUCTION

The Fuels and Lubrication thrust advances the pervasive technologies of aircraft and airbreathing missile fuels, combustion, lubricants and lubrication systems. Most of the effort supports the Integrated High Performance Turbine Engine Technology (IHPTET) initiative. Other programs, notably JP-8+100 with its improved thermal properties and thin-dense chrome and ceramic bearings with their enhanced corrosion resistance, will transition directly to deployed weapon systems. Continual dialogue with customer organizations helps ensure technology efforts are focused to satisfy user needs. Also, it helps to identify operational problems to which our expertise may be brought to bear. Funding and subthrusts dedicated to this thrust technology area are shown in Figure 2.1

USER NEEDS

This thrust is structured in response to Mission Area Plans (MAPs) and associated weapon system user needs. These needs are identified through the Technology Master Process (TMP) – as discussed on page 29 – and are reported in the Technology Investment Requirements Report (TIRR). This report is prepared by Aeronautical Systems Center (ASC) for Air Force Materiel Command (AFMC).

The TMP process provides unified guidance to the Air Force laboratories and thereby provides a basis for focusing laboratory thrusts to address current and projected user needs. Weapon system needs that we currently address include:

- Increased unrefueled range,
- Reduced IR signature (including visual and acoustic),
- Improved reliability, maintainability and supportability (including repairability) of all components,
- Reduced expendable lubricants,
- Removal, disposal and replacement problems with hazardous materials,
- Increased aircraft performance, and
- Reduce bleed air thrust losses.

Additional long term study efforts that we participate in focus on concepts for projected future user needs. They include:

- Toxicity, pollution and mitigation,
- Minimization of functional fluid types, and
- Gearbox and mechanical system life.

Our primary customers are the Air Combat Command, Special Operations Command, Combat Search and Rescue and the Air Mobility Command. Their needs cross many command/theater boundaries. In addition, we are supporting Warner Robins Air Logistics Center (WR-ALC) by addressing operational problems on the H-1 flight-line heater including cold weather start-up and fuel coking.

GOALS

Specific goals have been formulated to address user needs as shown below. These are quantified in Figure 2.2 and are phased with the IHPTET initiative.

- Improved fuels,
- Improved aircraft thermal management cooling capability,

- Improved engine lubricants,
- Advanced combustor concepts, modeling and diagnostics,
- Reduced engine emissions,
- Improved lubrication system mechanical components, and
- Increased reliability and supportability through reduced maintenance and lower life-cycle-costs.

MAJOR ACCOMPLISHMENTS

During the past year, two additives that meet the JP-8+100 goals to increase bulk fuel temperature capability to 425°F and increase the fuel nozzle wetted wall temperature to 500°F were identified and extensively evaluated. Tests were conducted in-house using laboratory rigs, engine component simulators, and a reduced scale F-22 fuel system/F119 engine simulator.

Considering those results and with support from the Air National Guard (ANG), San Antonio Air Logistics Center, and the Aeronautical Systems Center/Engine System Program Office, JP-8+100 was validated in several different engine tests. This culminated with a flight test at Edwards AFB in an F-16 with an F100-PW-220 engine.

All engine tests showed a significant reduction in fuel system fouling. Furthermore, with the positive results of the F-16 flight test, the improved fuel was cleared for testing in an operational environment. Consequently, an 18-month field demonstration of JP-8+100 was started in November 1994 at Kingsley Field, Oregon. Detailed tracking metrics were developed to validate maintenance cost reductions in eighteen F-16 aircraft assigned to the ANG and in several pieces of ground support equipment (i.e., start carts, air compressors, bomb loaders, etc.).

Dissolved oxygen plays a critical role in the fouling chemistry of thermally stressed aviation fuel. Researchers have developed a new laser based diagnostic technique that provides continuous data on the amount of dissolved oxygen in the fuel. Increased understanding of dissolved oxygen chemistry will accelerate the development of advanced fuels and ultimately reduce aircraft downtime due to fuel system maintenance. The new apparatus not only has significant advantages and unique capabilities, but is also more compact and costs less than equipment in use.

Current fuel system icing inhibitors are toxic and will be regulated under pending Environmental Protection Agency clean air and water act legislation. A candidate environmentally safe, non-toxic fuel system icing inhibitor derived from sugar was synthesized and tested in the laboratory. The new material, developed under a joint program

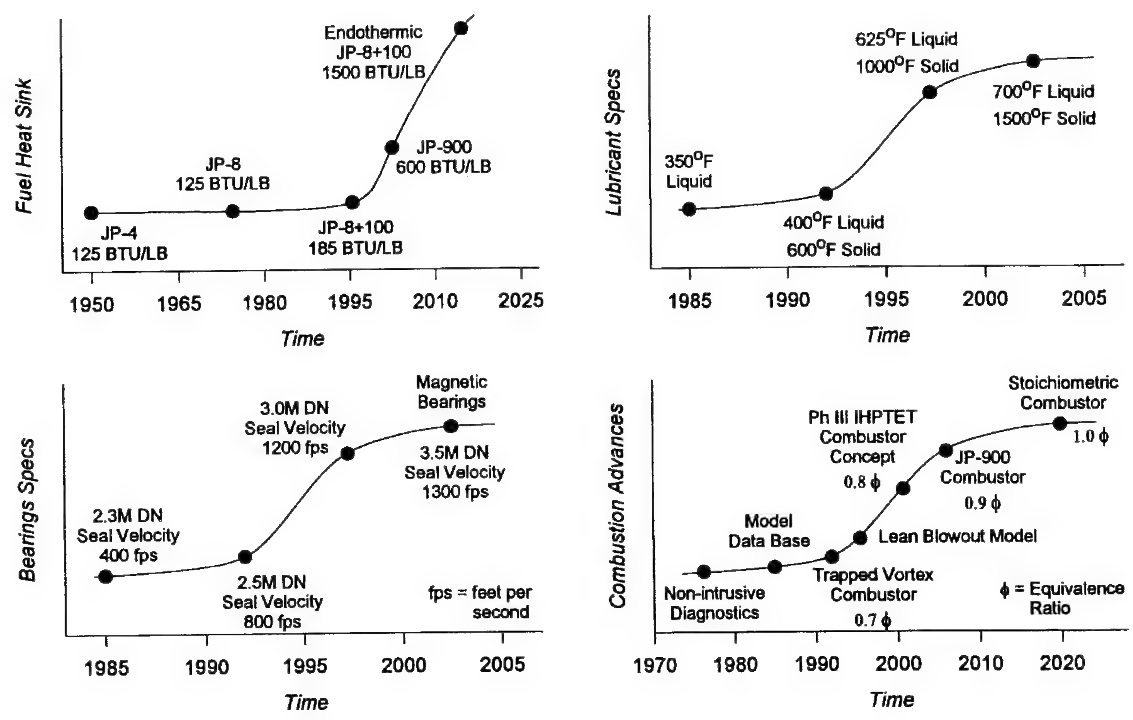


Figure 2.2: Fuels and lubricants quantified goals

with the Navy, is non-toxic and environmentally benign.

A unique combustor has been designed in-house that utilizes a trapped vortex (TV) to provide flame stability. This simple and compact combustor shows excellent promise for combustor applications. The flame is stable over a range of fuel to air ratio 10 times greater than conventional combustors, resulting in reduced flameouts. Overall pressure losses through the combustor are lower. In addition, the combustor produces greatly reduced oxides of nitrogen (NO_X) – an ozone depleter – while maintaining a combustion efficiency exceeding 99%.

Two theoretical endeavors have shown remarkable results. One effort indicates how locally high NO_X concentrations are produced in combustor primary zones. These results have been verified experimentally with phase-locked laser measurements with excellent agreement to the computational result. Discovery of this mechanism is unique to our technology area and has not been presented in the scientific community by others. The second effort has produced a unified theory on premixed and diffusion flames for simple flame systems. This code provides a smooth transition from premixed to diffusion flames. These results have been validated in the laboratory with very good agreement using hydrogen and methane fuels.

Liquid lubricant development is focused on IHPTET propulsion technology goals. It is closely coordinated with lubricant base material and additive research efforts in the Materials and Processes technology area and with related government, academic, and industrial research centers. Military specification MIL-L-7808K has been issued and vendor qualification is in process. This lubricant offers excellent temperature performance up to 400^{o}F and meets IHPTET Phase I goals. It also exhibits reduced carbon deposition tendencies. This oil will be initially employed in the F-22 aircraft and ultimately used fleetwide. Anticipated benefits include reduced engine maintenance cost and increased operational readiness.

A higher temperature lubricant (up to 625^{o}F) has been developed and will be demonstrated late this year in an advanced core engine. Fully compatible bearing materials are under development to realize the full potential of this new, high temperature lubricant in meeting Phase II IHPTET engine requirements.

Vapor phase lubricant technology continues to show promise in addressing advanced expendable engine requirements. In concert with industry and private research groups, a vapor phase lubrication system is being designed for a 1997 IHPTET Phase II Joint Expendable Turbine Engine Concept (JETEC) demonstrator.

Development efforts continue on sensors to detect the presence of hazardous and reclamation-inhibiting contaminants in waste/used turbine engine oils. This development will lead to a simple, effective, and environmentally responsible process for segregation, recycling, reclamation, or disposal of used oils. A prototype used engine oil collection facility is being evaluated at Edwards AFB. Other military and commercial facility demonstrations have been scheduled. Rapid transfer of this environmental technology to the civil sector is expected.

Field support to operational commands has been very successful and continues to grow in importance and emphasis. For example, our support in resolving incidents of foaming and oil pressure fluctuations in C-130 aircraft engines has concluded. Resolution of the problem relied on our understanding of lubricant foaming and employed sophisticated in-house developed analytical capabilities. Our support resulted in dramatic increases in operational readiness with significant cost savings.

Thin-dense chrome (TDC) coated turbine engine bearing races have been evaluated in a comprehensive series of load and endurance rig tests. Full scale engine testing is in process. This effort will culminate in Engineering Change Orders submitted to the Oklahoma Air Logistics Center to insert TDC bearings into fielded F110 engines. Full conversion to these bearings will save the Air Force $14 million per year in bearing replacements through reduced corrosion.

Ceramic bearing components also play a role in corrosion resistance. Extensive rig testing of ceramic balls in the no. 3 bearing of the F117 engine (C-17) is progressing as scheduled and is expected to transition in 1996.

A cesium-based coating for ceramic rolling element bearings was formulated in-house to support expendable engine programs with industry. These self-lubricating bearings were run at 1250^{o}F for up to 100 hours while maintaining their critical mechanical properties. Demonstration of the technology in a full gas generator is expected in FY97.

Balancing rotor thrust loads remains a challenge in advanced gas turbines. The standard approach of bleeding compressor air reduces engine cycle efficiency. Alternative approaches such as tapered roller and deflection pad bearings have been successfully demonstrated. Tapered roller bearing technology is expected to be validated in a military gas generator in FY97. Deflection pad technology will leap frog the traditional validation route via use in an LT101 commercial helicopter engine.

CHANGES FROM LAST YEAR

With support from the ANG, the JP-8+100 program was accelerated from laboratory testing to a field demonstration involving eighteen F-16 aircraft. Schedules have been revised to accelerate the testing of additional fuel additive packages to ensure wider availability and lower cost. Recent programs have been initiated to determine the impact of the fuel additive on ground handling activities such as filter coalescence and additive injection.

The effects of fine filtration on turbine engine lubricant system condition monitoring for predicting wear and impending failure is under study. This will lead to the optimization of oil filter porosity while reducing component wear, retaining oil system diagnostic capability and improving operational life, readiness, and reliability.

Design of a full magnetic bearing system for a single spool gas generator has begun. Demonstration is expected in FY97. This will be followed by extension of the technology to a dual spool system for a full turbofan engine evaluation. The magnetic bearings, combined with an integral starter/generator and electric accessories, will eliminate the need for a towershaft, gearbox and liquid lubricant. These factors will result in significant weight and operational and maintenance cost reductions.

MILESTONES

The C-17 aircraft engine hybrid ceramic bearing program, funded by ARPA, will finish in FY95 producing a more durable bearing. The final specification for an improved JP-8 fuel (JP-8+100) will be released in FY98 with a qualified product list of additives. Figure 2.3 outlines the specific timelines for other milestones and the four major technology areas being pursued.

- **High Heat Sink Hydrocarbon Fuels** are being developed to reduce fuel fouling/coking in current systems and to provide additional heat sink and thermal stability for future systems. The JP-8+100 validation program was accelerated due to need and support of the ANG. A detailed impact of the improved fuel on flight operations is being conducted at Kingsley Field and will continue through FY96. Additional additive candidates are being sought and tested to assure wider availability and to meet the cost goal of no more than one-tenth of a cent per gallon. Research objectives have been outlined to ensure the improved fuel will be available for fleet wide transition by FY98. JP-900 and endothermic fuels offer solutions for significant improvement in aircraft thermal management with a low maintenance lighter fuel systems for high speed propulsion systems. Endothermic fuel applications extend to scramjet and combined-cycle engine technologies. Responsive field support to help solve operational problems continues to be a high priority.

- **Combustion** research efforts are being conducted to reduce the risk and cost associated with developing affordable, durable high performance, low maintenance turbine engines that operate efficiently within air pollution guidelines and have high thrust-to-weight ratio and low specific fuel consumption. Research directed at providing high heat release capability for IHPTET Phase III has been expanded to include the control of oxides of nitrogen at high power and unburned hydrocarbons and carbon monoxide at low power. The emissions suppression aspect of the effort is supported by AFMC/CEV (Civil Engineering Environmental Management). Replacement fire suppressant agents for the banned Halon 1301 will be evaluated in a well stirred reactor to better understand the extinguishing mechanism. This information is vital to specifying the agent delivery systems and the quantities of agent to be loaded into a particular fire suppressant system.

- **Lubricants** research involves both in-house and contractual efforts to enhance the state-of-the-art of lubricants for superior performance in operational engines as well as development of advanced lubricants to satisfy the revolutionary needs of the IHPTET initiative. Research continues to develop lubricant diagnostic techniques to warn of impending catastrophic failures in engine lubrication systems. Weapon system payoffs include reduced cost of maintenance and

operation and enhanced mission readiness and reliability. Research is also focused on development of environmentally responsible and affordable solutions for used oil collection, storage, reclamation and disposal. Responsive field support to solve operational problems continues to be high priority.

- **Lubrication Systems** address turbine engine mainshaft mechanical support systems (bearings, seals, dampers) and gearbox components that are being developed for upgrade of current engines and IHPTET technology demonstrator engines. Performance, durability, and cost are tailored to meet requirements of specific applications. For man-rated IHPTET applications, high performance, yet affordable, systems with high durability and reliability are emphasized. Expendable IHPTET concepts emphasize low cost as well as high performance. All IHPTET concepts require mainshaft support systems that enable higher engine operating temperatures and increased engine rotational speeds while also supporting weight reduction goals. Innovative support system concepts must be employed to meet the IHPTET Phase II and Phase III goals. Currently under development are systems to operate with high temperature liquid lubricants, various forms of solid lubrication, and vapor phase lubrication. Active magnetic bearings – another revolutionary concept under development – are essential for successful Phase III IHPTET technology demonstrator engines.

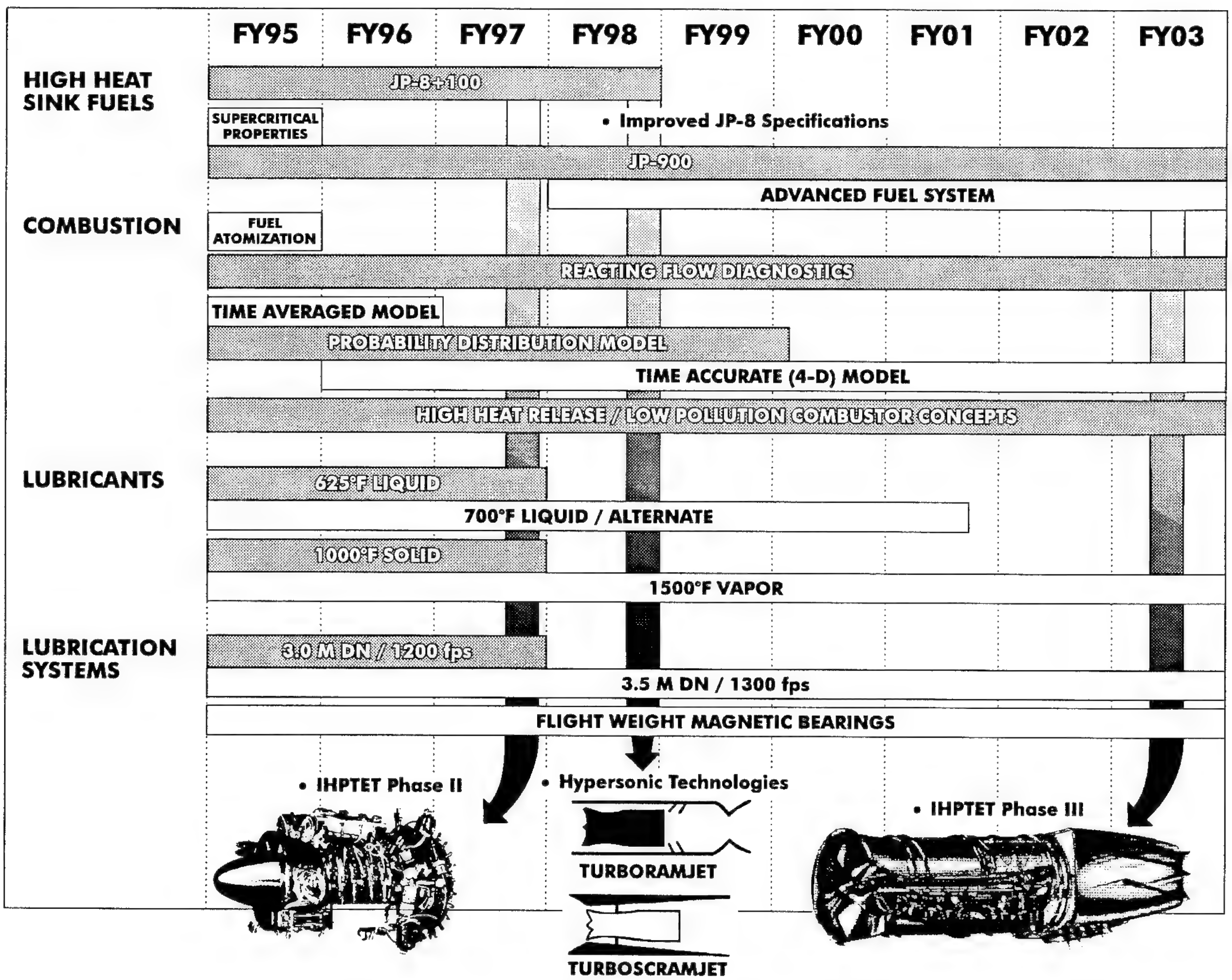


Figure 2.3: Thrust 2 - Fuels and Lubrication

THRUST 3: HIGH SPEED PROPULSION

Double missile engine capability by 1997 and provide Mach 0 to 8 hydrocarbon propulsion technology for the 21st century

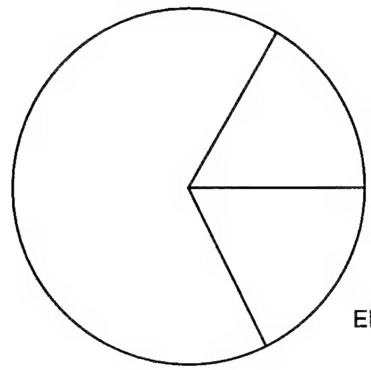


Figure 3.1: High Speed Propulsion subthrusts ($13.4M)

INTRODUCTION

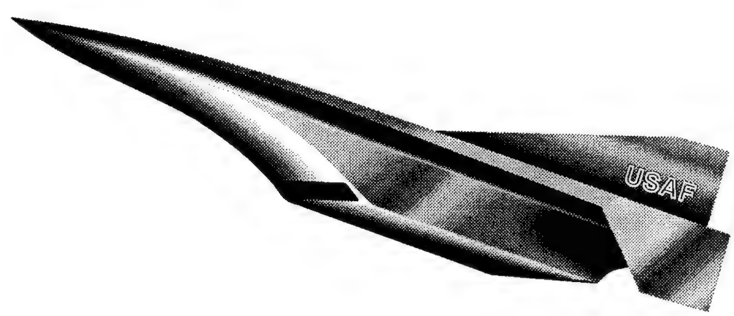
The High Speed Propulsion thrust is focused on the Air Force vision "Global Reach - Global Power." In support of this vision, the thrust develops high speed (short timelines) and long-range (increased operational area) propulsion systems that balance high performance, supportability, and cost for future missiles, aircraft, and space launch vehicles. The thrust provides assessment and demonstration of unconventional airbreathing propulsion systems such as ramjets, dual-mode ramjets, and combined-cycle engines to ensure future propulsion options for high speed, rapid response air defense systems. Air Force funding and subthrusts supporting these activities are shown in Figure 3.1.

The high speed propulsion thrust is currently being integrated with a Wright Laboratory Hypersonic Technology (HyTech) initiative as directed by the Secretary of the Air Force. The primary goal is to provide revolutionary technology options to satisfy future Air Force needs by addressing user deficiencies. Mach 0 to 8 high speed airbreathing propulsion is the key enabling technology focus of the HyTech initiative. HyTech funding to augment high speed propulsion technology development is anticipated, but not yet finalized.

USER NEEDS

The High Speed Propulsion thrust provides a blend of near-term "user-pull" technologies along with high payoff advanced "technology push" programs to meet current and future aerospace propulsion needs. The thrust provides enabling technologies that address many user needs identified in the Air Combat Command Counter-Air, Air-to-Surface, Theater Missile Defense, and Space Command Space Lift Mission Area Plans (MAPs) as well as the Aeronautical Systems Center Technology Investment Recommendation Report (TIRR). High Speed technology needs also were identified by the Technical Planning Integrated Product Teams (TPIPTs) as part of the Technology Master Process (TMP). Unclassified needs are as follows:

- Counter Air Needs: Increase in kinematic performance for missiles.
- Air-to-Surface Needs: Increase range and multiple kills per pass.
- Theater Missile Defense Needs: Rapid response capability against theater and ballistic missiles.



Hydrocarbon fueled dual-mode ramjet for Mach 8 cruise

- Space Lift Needs: Cost effective space lift capability that enables timely support of military forces.

- Support system concepts identified by each TPIPT that address user needs and deficiencies.

All efforts are coordinated and/or conducted jointly with NASA, Navy, and Army counterparts to provide a nationally unified high speed propulsion program.

GOALS

The goal of the High Speed Propulsion thrust is to address the deficiencies and user needs identified in the MAPs and the TIRR. This will be accomplished by balancing performance, supportability, and costs of both upgrades and new high speed, long range advanced propulsion systems. The two main goals of the High Speed Propulsion thrust are as follows:

Double missile propulsion capability by FY97. Flight ready Variable Fuel Flow Ducted Rocket Ramjet (VFDR) engine technology will nearly double the engine total impulse of a conventional solid rocket, resulting in a dramatically increased air-to-air missile kinematic capability. Increases in kill ratio, no-escape zone, average missile velocity, launch range, and a reduction in time-to-target provide the capability to meet current and emerging foreign air-to-air missiles and result in increased missile lethality and launch aircraft survivability. Air-to-ground missiles will also benefit with higher average flight speeds and reduced time-to-target.

Provide Mach 0-8 hydrocarbon propulsion capability for the 21st Century to support future missiles, aircraft, and space launch vehicles. Combined-cycle and dual-mode ramjet/scramjet engine technologies using storable liquid fuels (JP like) will provide revolutionary long range, rapid response operational capabilities for future system applications such as locating and striking time critical targets, stand-off attack, intelligence, reconnaissance, and deep interdiction missions. Examples of future applications include a fast reaction

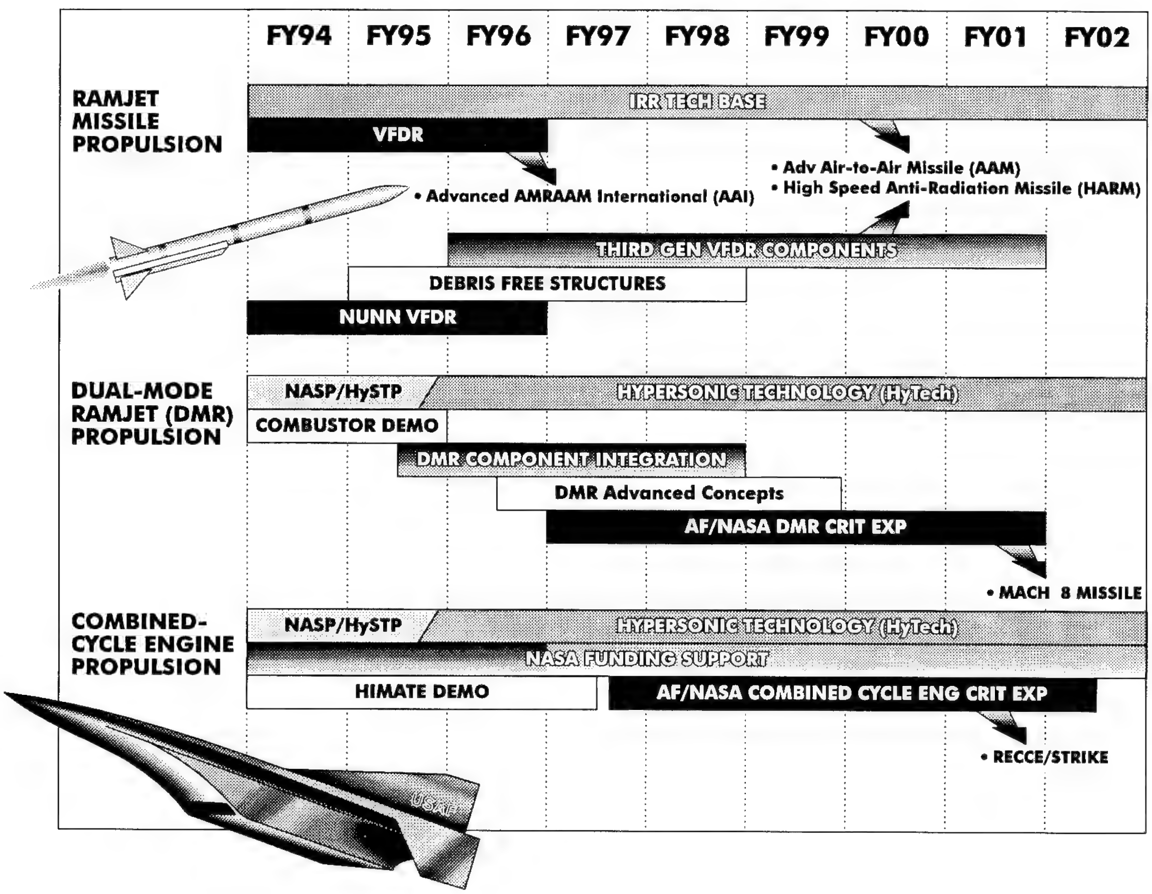


Figure 3.2: Thrust 3 - High Speed Propulsion

stand-off theater weapon to be utilized against highly mobile "SCUD-type" weapons. Other applications include first stage engines for orbital launch vehicles that enable larger payloads and hence, more affordable access to space. These high speed systems also provide the capability for sustained high speed flight for both military and commercial applications.

Use of storable hydrocarbon fuels will provide a dramatic advantage in supportability for future high speed systems. The hydrocarbon-based liquid fuel effort will expand the use of storable hydrocarbon fuels up to Mach 8 for dual-mode ramjets and Mach 6 for combined-cycle engines. Recent developments in high heat sink endothermic fuel technology (a fuel that absorbs a tremendous amount of heat through chemical decomposition) has enabled the use of conventional type jet fuels in high speed propulsion systems. As an example, airplane-type operations for up to Mach 8 vehicles can be retained using current maintenance and fuel handling practices, resulting in relatively low acquisition and life cycle costs.

Significant advancements in hydrogen fueled high speed propulsion have been achieved under the National Aero-Space Plane (NASP) and Hypersonic Systems Technology Program (HySTP) and further technology development is expected to follow in a collaborative effort with NASA under the currently emerging HyTech initiative.

MAJOR ACCOMPLISHMENTS

Major accomplishments in high speed propulsion include:

- Demonstrated VFDR nozzleless booster at required temperature extremes (-65°F to 145°F) and produced the highest total impulse ever achieved in this configuration.
- Demonstrated VFDR ramburner with improved insulation that reduced combustor wall temperatures 200°F-500°F.
- Demonstrated VFDR advanced migration barrier material that reduces the booster liner thickness and survives the -65°F to 145°F temperature cycling requirement.
- Completed initial development of low smoke ducted rocket fuels with 10% more energy than the baseline and developed somewhat smokier fuels that offer 50% more energy than the baseline fuel.
- Completed design and initiated fabrication of an air-core enhanced turborocket combustor/ diffuser sector for performance testing to Mach 5.
- Completed design and fabrication of a dual-mode ramjet/scramjet burner for performance testing to Mach 7.
- Initiated a hydrocarbon fueled dual-mode ramjet/scramjet component integration program to demonstrate a complete engine (inlet, isolator, combustor and nozzle) up to Mach 8 flight conditions.

CHANGES FROM LAST YEAR

Two major changes have occurred since last year. First, the High Speed Propulsion thrust hydrocarbon ramjet, dual-mode ramjet, and combined-cycle engine programs are currently being synergetically integrated with a nationally coordinated Wright Laboratory Hypersonic Technology (HyTech) initiative as directed by the Secretary of the Air Force. This new plan will close out the HySTP program and transition the accomplishments made into an exploratory development program.

The primary goal of HyTech is to develop those critical enabling hypersonic technologies required to support the hypersonic concepts needed to solve documented user deficiencies. Concepts will include accelerating missiles, hypersonic cruise missiles and aircraft, and reusable launch vehicles.

The focus will be on hypersonic airbreathing propulsion systems currently being developed by the High Speed Propulsion thrust and NASA. Additionally, vehicle conceptual designs, trade synthesis, high temperature materials, and structures will be pursued. Funding for some high speed propulsion programs will come from the HyTech program. Progress in many of the high speed propulsion programs has been significantly delayed in FY95 as a result of guidance shifting the major funding source to the HyTech program element.

The second major change from last year is a substantial delay in funding for the VFDR program (6.3 advanced development funds). Although funding was appropriated by Congress, release of the funds is conditional. Efforts are currently underway to meet these conditions. VFDR technology efforts (exploratory development funds) and Nunn funded international ducted rocket programs are progressing as planned.

MILESTONES

To manage the required technology developments, the High Speed Propulsion thrust is divided into three main technology areas: ramjets, dual-mode ramjets, and combined-cycle engines (Figure 3.2). The following milestones have been established to provide a timely, logical path to meet stated needs and goals.

- Ramjet engine technology milestones are set to provide VFDR engine technology by FY97. Interim technical milestones include demonstrating full scale gas generator fuel formulations with a 10% increase in fuel energy over the baseline fuel (FY95), demonstrating full scale booster operation that delivers 100% of the total impulse goal and performs at the required temperature extremes (FY95), evaluating and demonstrating "unchoked" ducted rocket technology that offers a simpler, reduced weight engine system (FY95), demonstrating integrated flightweight VFDR engine boost-to-ramjet transition testing, completing direct connect performance documentation and environmental testing (FY96), and initiating a next generation ramjet program to incorporate the latest technology developments (FY96).

- Dual-mode ramjet milestones are equally well established. The main activity occurring in FY95 is integrating dual-mode ramjet programs with the Wright Laboratory Hypersonic Technology initiative. Technical milestones include integrating an endothermic fuel heat exchanger/reactor with a dual-mode ramjet combustor and conducting performance testing up to Mach 7 (FY95), and initiating a dual-mode ramjet/scramjet component integration program (FY95) for documenting dual-mode ramjet performance in a fully integrated (inlet, combustor, and nozzle) engine test up to Mach 7 using storable hydrocarbon fuels (FY97).

- Combined-cycle engine programs and milestones are also being integrated with the Wright Laboratory HyTech initiative. Technical milestones include completing in-house facility preparations and integrating hardware to support a joint Air Force/NASA turboramjet hyperburner test program (FY96), initiating in-house testing of the hyperburner to simulate high Mach flight conditions (FY97), and completing testing of an air-core enhanced turborocket combustor/diffuser sector to Mach 5 (FY96). Also, completing development of critical component technologies (ramburners, swirl combustors, and heat exchanger/reactors) for the joint Air Force/NASA High Mach Turbine Engine (HiMaTE) initiative (FY96), and lastly, initiating a joint Air Force/NASA critical experiment program for demonstrating a fully integrated combined-cycle engine over the Mach 0-6 flight regime (FY97).

- The High Speed Propulsion thrust continues exploring and developing new and innovative high payoff propulsion concepts via the Small Business and Innovative Research (SBIR) program. Two examples are the solid fueled Air-Turbo Rocket (ATR) and the Pulsed Detonation Engine. The solid fueled ATR offers the potential to improve fuel specific impulse 400% over a solid rocket while maintaining the desirable supportability advantages. ATR milestones include solid fuel developing and testing (FY96) and initiating a joint Air Force/Army/Navy exploratory development program (FY97). Successful low frequency testing of the pulsed detonation engine (PDE) has demonstrated tremendous thrust-to-weight advantages (FY95). A follow on effort will be demonstrating a high frequency multi-tube pulse detonation wave engine for high speed missile applications (FY96).

THRUST 4: AEROSPACE POWER

Reducing cost of Global Projection:

Double power system reliability and reduce ground support equipment by the year 2000

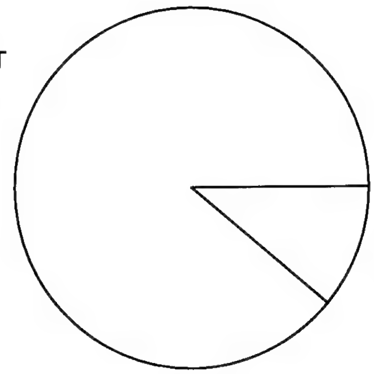
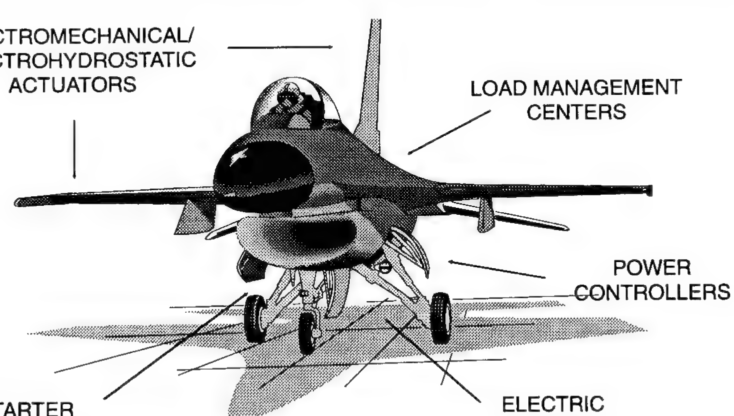


Figure 4.1: Aerospace Power subthrust ($20.0M)

INTRODUCTION

The cost to produce, maintain, and support our technology weapon systems is one of the major issues the Air Force and DoD is facing. Technology options must be made available to ensure that aircraft designs are ultra-reliable, easier to maintain, supported by less equipment and personnel, more survivable, lower in cost, and higher in performance. Additionally, global economics are forcing our current fleet into extended service lives. In order to support and maintain this aging fleet, technology retrofit options must be focused on reliability, maintainability, and supportability (RM&S) and be made available in a cost effective and timely manner.

The challenge then, is to retain our strength and air superiority – but to do so with less. To address this challenge, we are focusing resources on electrically-driven subsystems in replacement of more conventional lesser reliable hydraulics, pneumatics, and mechanically-driven subsystems. This "more electric" focus will permit us to reduce the number of power transfer systems and utilize ultra-reliable miniaturized high power electronics, fault tolerant power distribution systems, and electric generators/motors/actuators to increase performance while reducing support equipment and costs. The "more electric" concept will not only improve our current aircraft effectiveness but is also seen as the technology direction of opportunity relative to commercial aviation, electric vehicles, and numerous other commercial applications. Funding and subthrusts dedicated to this technology area are highlighted in Figure 4.1.



Aging aircraft targeted for MEA technologies

USER NEEDS

The Aerospace Power thrust provides enabling technologies that address numerous operational deficiencies and needs identified by the Technology Master Process (TMP) – as described on page 29. This process relies on Technical Planning Integrated Product Teams (TPIPTs) and mission area planning to collect, prioritize, and categorize user needs. These activities in turn are documented in Mission Area Plans (MAPs) and the Technology Investment Recommendation Reports (TIRR).

MEA and special purpose power technologies are responsive to these weapon system needs through technology efforts in the areas of electrical, electromechanical, electrochemistry, power semiconductor, electromagnetic, plasma research, and thermal control. Specifically, MEA supports the Counter Air and Air-to-Surface MAPs through programs such as the Maintenance Free Battery System and the 270-Vdc Power Management and Distribution for MEA. Finally, the Airlift and Air Refueling MAPs specifically identify MEA as providing key technologies to enhance aircraft performance and supportability. A consolidated list of needs and MAP references are shown in Table 4.1.

MEA focuses on these needs through the replacement of centralized hydraulics, bleed pneumatics, and gearboxes with highly reliable electrical systems. Reliability improvements are accomplished through fault tolerant electrical power distribution systems that supply conditioned power to electrically driven flight controls and other subsystems.

An infrastructure technology need is being worked for Ogden Air Logistics Center. A catalyst is currently used with the hydrazine powered F-16 emergency power unit (EPU). All EPUs have their catalyst changed when undergoing depot maintenance. Methods are being investigated to determine if the previously installed catalysts can be reinstalled or rejuvenated. Potential cost savings are $3,000 per unit.

GOALS

The vision of this thrust is to reduce operational costs, improve performance, and decrease global force projection costs through the implementation of MEA technologies. These technologies offer significant increases in subsystem and component reliability, reduced dependence of aerospace ground equipment (AGE), and increases in battle damage tolerance. Additionally, these technologies support next generation aircraft while benefiting weight, performance, and cost. More specifically, the goals of MEA are to:

- Reduce life cycle costs through improved component reliability,
- 30-50% reduction in AGE,
- Eliminate central hydraulic system,
- 2-3 fold increase of fault tolerance of electrical power distribution system,
- Improved aircraft performance and flight control through the use of high temperature semiconductor electronics, and
- Major system level improvements in RM&S.

Core MEA technologies being pursued include fault tolerant power generation, management and distribution systems, motor drives, miniaturized high power electronic devices, power conditioning units, and energy storage concepts. Recognizing that these technologies provide near-term solutions to our aging aircraft, they also form the technology base for future military aircraft. Studies completed by major airframe contractors indicate significant payoffs in reliability, maintainability, and life-cycle- cost while enhancing survivability and performance. Quantifiable goals for more electric versions of the F-16 and F/A-18 are:

- Reliability and maintainability improvements of 15% and 10% respectively,
- Reduced C-141 deployment loads by up to 20%, and

Table 4.1 : Consolidated list of needs and MAP reference

SELECTED TIRR USER DEFINED NEEDS	USING COMMAND & MAP
• Increased range, payload, and maneuverability	ACC: Counter Air, Air-to-Surface SOC: Joint Air Battlefield, Combat Support, Force Application, Psychological Ops AMC: Air Refueling, Air-to-Surface
• Next attack aircraft	ACC: Counter Air, Air-to-Surface SOC: Joint Air Battlefield, Combat Support
• Increased reliability, maintainability, and supportability (RM&S) for AMC aircraft	ACC: Counter Air, Air-to-Surface AMC: Air Refueling, Airlift
• Reduce signature of SOF, attack, and fighter aircraft	ACC: Counter Air, Air-to-Surface SOC: Combat Support, Joint Air Battlefield, Force Application
• Alternative propulsion/power (fuels) capability	Potential for all mission areas

ACC: Air Combat Command SOC: Special Operations Command AMC: Air Mobility Command

- Decreased workforce by 15%, and vulnerability improvements approaching 15%.

The combination of reduced downtime and reduced vulnerability provides 10-15% additional sorties from the same number of aircraft. Considering a block of 750 aircraft, the same mission capability can be obtained with about 15% fewer aircraft. These improvements provide direct support to the "Global Reach-Global Power" philosophy.

Additional technologies being pursued are power components for special purpose applications. Examples include ground power, high or pulse power, and missile power. The core technologies most supportive of these applications are high temperature superconductivity and advanced electrochemistry systems. Planned technology demonstrations will occur over the next five years.

Although the focus is toward special purpose applications, the technologies being developed will have direct applications to other systems including near-term aircraft retrofits. Examples of current systems that may utilize this technology include Airborne Warning and Control Systems (AWACS), Joint Strategic Target and Recognition Systems (JSTARS), and tactical weapon systems such as the Advanced Medium Range Air-to-Air Missile (AMRAAM) and the AGM-130.

MAJOR ACCOMPLISHMENTS

Major accomplishments in aerospace power technology are plentiful. They include the following.

The Power Management and Distribution for More Electric Aircraft (MADMEL) program supports the F-22 System Program Office (SPO). To ensure transitionability, the MADMEL and F-22 teams continue to work together. This program is currently in the fabrication phase. Vendors have been selected to develop key components such as the electrical load management centers and the converters and inverters. In addition under the MADMEL program a task to integrate a 250-kW starter/generator, a bidirectional electromechanical power contractor, and an electrohydrostatic actuator with its motor controller has been initiated to provide risk reduction of key subsystems.

The magnetic bearings have been fabricated and tested, and the rotor/bearing subsystem integration/test is in process for the Integrated Power Unit (IPU). The IPU is a single aircraft power unit that can replace and perform the functions of three separate units: main engine starting, auxiliary power, and emergency power. Application of this unit will result in significant reductions in AGE.

The 20-year Maintenance Free Aircraft Battery System is under development. Tests of this hardware should start in June 1995. Systems integration has been initiated and delivery to the JSTARS SPO is scheduled for FY96. Special Operations Forces have also expressed an interest in this battery.

An electrical power system load management center was successfully developed and demonstrated. This unit was selected to be used on the Advanced Hercules II (C-130J) and by Bombardier Aerospace Group – North America on their long range high speed Global Express business jet. This technology has embedded intelligence that provides fault tolerance and improved reliability for the power system.

The hardware for the C-141 Electric Starlifter program – a joint program with Air Vehicles – has been developed and is under flight justification testing. This moves Air Mobility Command closer to retrofitting the hydromechanical actuators of the aileron system with new electronic integrated actuators. This will reduce the cost of maintaining transport aircraft while increasing their reliability.

A 250-kW starter/generator switched reluctance machine has been fabricated along with the associated power and control electronics. The machine has been tested in generate mode at power levels of 120-kW at flight idle speeds in excess of 12,000 RPM. Incorporating the internal version of this design into future engines will eliminate 110 pounds of system weight and reduce the fuel consumption by more than 2% while improving systems reliability and maintainability.

Developed hardware is under test for a free-piston compressor for the C-17 Onboard Inert Gas Generation System (OBIGGS) that offers much improved reliability (5-10 fold) over the currently used unit. This compressor offers mass savings of approximately 50% (110 pounds per C-17 ship set) and is intended to be a direct drop-in replacement for the current recharge compressor.

Activities of the triservice/NASA MEA Joint Planning Team are progressing toward the completion of a More Electric Initiative (MEI) national plan.

Considering specific Scientific Advisory Board Summer Study recommendations, joint efforts to provide essential ground demonstrations and a flight test of an electrically actuated stabilator were initiated with Air Vehicles, Materials and Processing, and Avionics technology areas.

A series of nontoxic monopropellants based on the oxidizer hydroxylammonium nitrate (HAN) are currently under production. These monopropellants are being evaluated as possible replacement propellants for the F-16 emergency power unit. Currently, the system uses hydrazine, a known mutagen and suspected carcinogen, as its monopropellant. So far, the program has reduced the number of possible fuel formulations from 10 to 4, and produced a laboratory scale gas generator with which to further evaluate the remaining monopropellants.

Filter and energy storage capacitors are a major component used in nearly all military systems. These capacitors are often a source of system failure due to electrical and thermal degradation. Therefore, the development of state-of-the-art, high temperature, polymer dielectric film was pursued and completed. This new material has a reliable temperature capability of 437°F. This is almost a two-fold increase in the state-of-the-art of current aircraft systems that use polycarbonate film. The improved electrical properties of the film will also reduce capacitor weight by 30-40%.

Use of passive thermal control devices such as heat pipes for electronics cooling is questionable when considering the high "g" loads experienced on today's fighter aircraft. Considering the initial success of in-house testing of an acceleration tolerant flexible heat pipe, testing of heat pipe type devices using capillary structures subject to acceleration induced forces typifying high performance aircraft have demonstrated the need for a fundamental understanding of transport phenomena. Fundamental research areas have been identified that address both the macroscopic and microscopic physics in order to predict device level performance of aircraft applications.

In summary, the existing science and technology programs, as well as planned MEA programs, continue to receive strong endorsements from the Air Combat Command, Air Logistics Centers, numerous SPOs, and other Air Force Materiel Command (AFMC) organizations. In direct response to the Air Force Acquisition Executive guidance and the Scientific Advisory Board, the aircraft power focus continues to emphasize MEA technologies that take advantage of the greater reliability and performance characteristics offered by advanced electrical and electronic components.

CHANGES FROM LAST YEAR

The Aerospace Power thrust has developed a firm relationship with the Warner Robbins Alternate Fueled Vehicle (AFV) SPO. Under a memorandum of agreement with AFV SPO, Wright Laboratory (WL) has provided technical consultation that has led to the development of a significant opportunity to infuse power electronics technology into upcoming hybrid vehicle developments. Advanced Research Projects Agency (ARPA) and the Department of Energy have sponsored a number of programs that have resulted in many versions of electric vehicles with varying amounts of power electronics technology employed in controls, motors, and battery systems.

The industry has been slow to embrace new power switching and supercapacitor technology that WL has helped develop to meet aircraft needs. As a result WL is negotiating to support two planned industry led efforts (funding sought through ARPA) with Cooperative Research and Development Agreements (CRDAs) to help industry utilize the benefits of advanced power switches and supercapacitors. Both of these efforts will develop hybrid electric power trains that will become the baseline for Warner Robbins purchases of medium and heavy duty flight line tugs and support vehicles.

During FY94, technologies such as switched reluctance starter/generators and 270-Vdc power components showed great promise in supporting the JAST demonstration program. These selective technologies were developed under the MEA initiative and demonstrate the crucial link between Science and Technology (S&T) efforts and future weapon system development/demonstration programs. With the tie to JAST, there was a misperception that all MEA activities were absorbed by JAST thereby resulting in a redirection of S&T funds to the JAST program. The MEA initiative has and will continue to cover numerous technologies that are beyond the mid 1999 technology availability date set by JAST. Additionally, the MEA initiative supports near term retrofit opportunities that directly support our nations aging fleet.

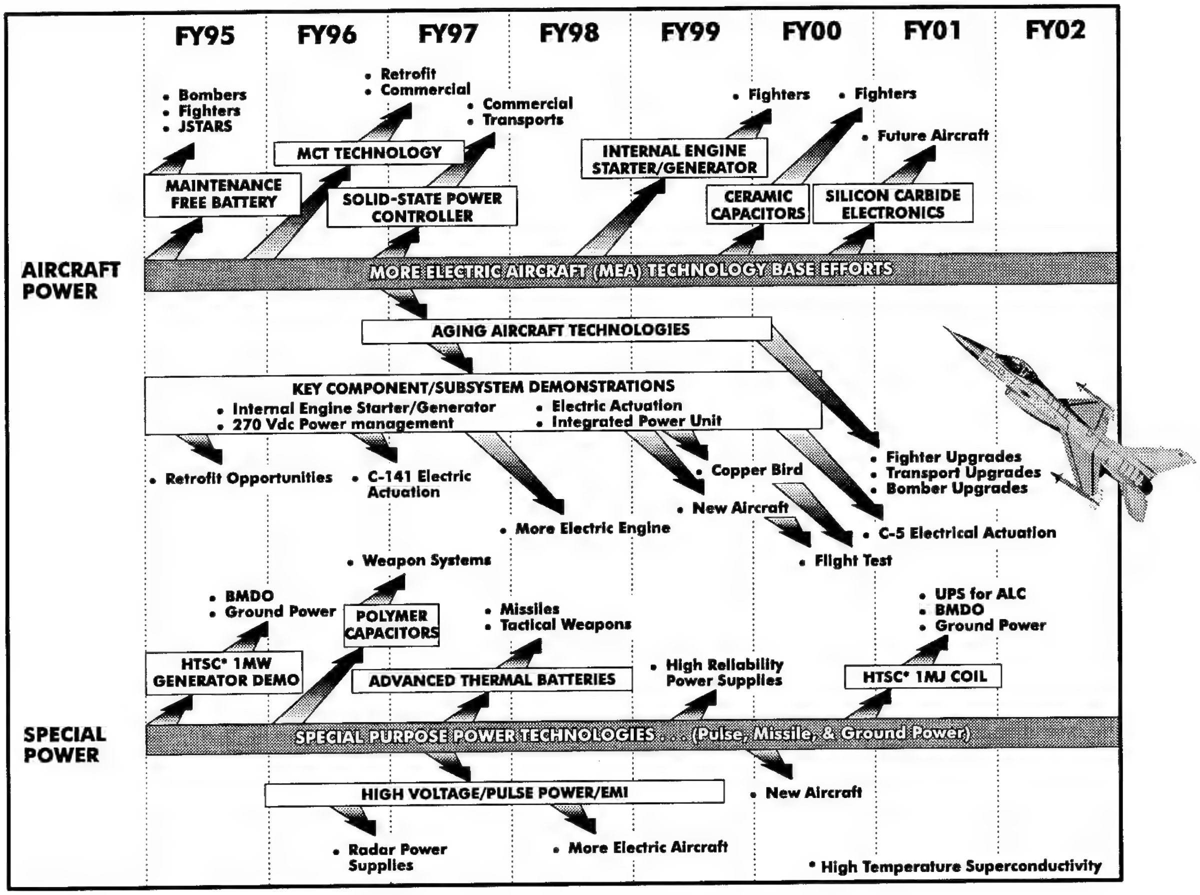


Figure 4.2: Thrust 4 - Aerospace Power

MILESTONES

Figure 4.2 highlights ongoing and planned efforts contained within both the MEA initiative and Special Purpose Power. Specific milestones include the transitioning of a maintenance free battery system to the JSTARS SPO (FY96), complete hardware flight justification tests and aircraft modifications of a C-141 with electrically actuated ailerons (FY95), initiate an in-service evaluation of the C-141 system (FY96), complete fabrication of high speed generator system for an integrated power unit (FY95), complete full testing and demonstration of the high speed generator (FY96), and perform critical 270-Vdc system level demonstrations (FY96-FY00).

Special purpose power applications include the demonstration of a three-fold improvement in specific energy density and a ten-fold increase in current throughput by using superconducting technology. Applications will include superconducting magnetic energy storage for back-up power, uninterruptable power supplies, and high power generator for advanced surveillance. Associated milestones include retrofitting an existing 1-MW cryoaluminum generator with high temperature superconducting coils (FY96) and testing of high temperature superconducting transmission lines "downleads" and coils for application to a superconducting magnetic energy storage device (FY96).

Electrochemistry technologies that support special purpose applications include an environmental initiative based on a nickel-metal hydride system. This technology is being pursued as a replacement to the currently used lead and cadmium battery systems. The nickel-metal hydride system will result in a 30% weight and volume reduction over current battery systems. Additional technologies include advancements in thermal batteries that support advanced tactical weapons and high voltage lithium electrochemistry that supports numerous ground systems.

Milestones relative to electrochemistry include a performance demonstration of a nickel-metal hydride system (FY96) and a partial stack demonstration of an advanced lithium based system (FY96).

GLOSSARY

AAI	Advanced AMRAAM International
ACC	Air Combat Command
AFAE	Air Force Acquisition Executive
AFB	Air Force Base
AFMC	Air Force Materiel Command
AFOSR	Air Force Office of Scientific Research
AF	Air Force
AFV	Alternate Fueled Vehicle
AGE	Aerospace Ground Equipment
ALC	Air Logistics Center
ALCM	Air Launched Cruise Missile
AMC	Air Mobility Command
AMRAAM	Advanced Medium Range Air-to-Air Missile
ANG	Air National Guard
APU	Auxiliary Power Unit
ARPA	Advanced Research Projects Agency
ASC	Aeronautical Systems Center
AST	Advanced Subsonic Technology
ATEGG	Advanced Turbine Engine Gas Generator
ATR	Air-Turborocket
AWACS	Airborne Warning and Control Systems
BLADE-GT	Blade Life Analysis and Design Evaluation for Gas Turbines
C^3I	Command, Control, Communication, and Intelligence
CRDA	Cooperative Research and Development Agreement
CRF	Compressor Research Facility
DDR&E	Director of Defense Research & Engineering
DMR	Dual-Mode Ramjet
DN	Diameter (mm) Times Speed (rpm)
DoD	Department of Defense
EPU	Emergency Power Unit
FAA	Federal Aviation Administration
FOD	Foreign Object Damage
HAN	Hydroxylammonium Nitrate
HiMaTE	High Mach Turbine Engine
HCF	High Cycle Fatigue
HSR	High Speed Research
HTST	High Temperature Superconductivity
HySTP	Hypersonic Systems Technology Program
HyTech	Hypersonic Technology
IHPTET	Integrated High Performance Turbine Engine Technology
IPT	Integrated Product Team
IPU	Integrated Power Unit
IR	Infrared
IR&D	Independent Research and Development
IRR	Integral Rocket Ramjet
JAST	Joint Advanced Strike Technology
JETEC	Joint Expendable Turbine Engine Concept
JP	Jet Propulsion
JSTAR	Joint Strategic Target & Recognition
JTAGG	Joint Turbine Advanced Gas Generator
JTDE	Joint Technology Demonstrator Engine
KEFH	1000 Engine Flight Hours
kW	Kilowatt
LCC	Life Cycle Cost
LO	Low Observable
MADMEL	Power Management and Distribution for More Electric Aircraft
MAP	Mission Area Plan
MEA	More Electric Aircraft
MEI	More Electric Initiative
MW	Megawatt
NASA	National Aeronautics and Space Administration
NASP	National Aero-Space Plane
NO_x	Nitrous Oxides
OBIGGS	Onboard Inert Gas Generation System
O&M	Operations & Maintenance
PDE	Pulse Detonation Engine
RAMTIP	Reliability & Maintainability Technology Insertion Program
RM&S	Reliability, Maintainability, and Supportability
S&T	Science and Technology
SAB	Scientific Advisory Board
SBIR	Small Business Innovation Research
SFC	Specific Fuel Consumption
SOC	Special Operations Command
SOF	Special Operations Forces
SPO	System Program Office
TAD	Technology Availability Date
TAP	Technology Area Plan
TDC	Thin Dense Chrome
TEO	Technology Executive Officer
TIRR	Technology Investment

	Recommendation Report
TMP	Technology Master Process
TPIPT	Technical Planning Integrated Product Team
TRF	Turbine Research Facility
TTO	Technology Transition Office
TV	Trapped Vortex
T/W	Thrust-to-Weight
UAV	Unmanned Air Vehicle
Vdc	Volts Direct Current
VCE	Variable Cycle Engine
VFDR	Variable Flow Ducted Rocket
VC	Vortex Combustor
WL	Wright Laboratory
WR-ALC	Warner Robins Air Logistics Center

TECHNOLOGY MASTER PROCESS OVERVIEW

Part of the Air Force Materiel Command (AFMC) mission deals with maintaining technological superiority for the United States Air Force by:

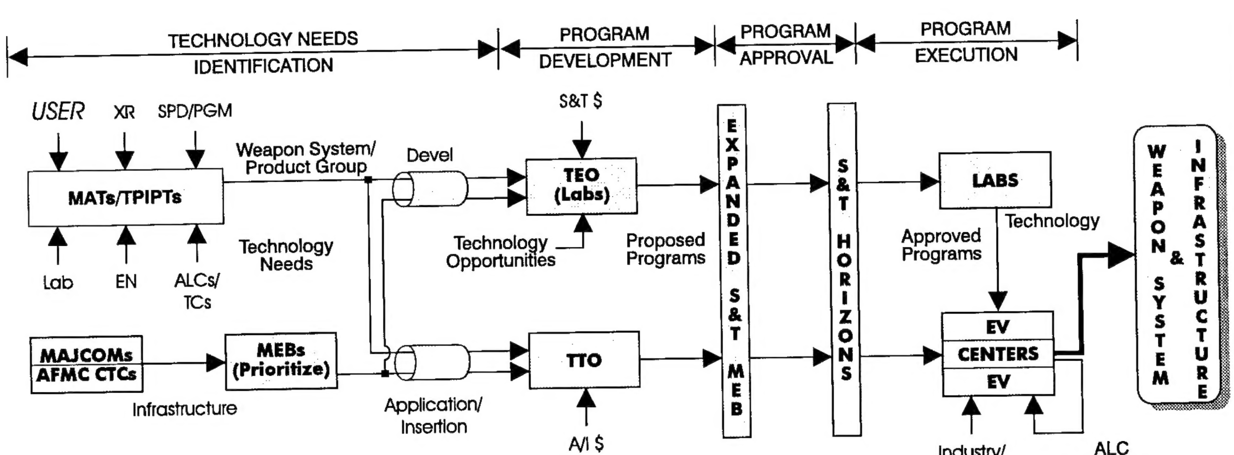
- Discovering and developing leading edge technologies,
- Transitioning mature technologies to system developers and maintainers,
- Inserting fully developed technologies into our weapon systems and supporting infrastructure, and
- Transferring dual-use technologies to improve economic competitiveness.

To ensure this mission is effectively accomplished in a disciplined, structured manner, AFMC has implemented the **Technology Master Process** (TMP). The TMP is AFMC's vehicle for planning and executing an end-to-end technology program on an annual basis.

The TMP has four distinct phases, as shown in Figure 6.1:

- Phase 1, **Technology Needs Identification** – Collects customer-provided technology needs associated with both weapon systems/product groups (via TPIPTs) and supporting infrastructure (via CTCs), prioritizes those needs, and categorizes them according to the need to develop new technology or apply/insert emerging or existing technology. Weapon system-related needs are derived in a strategies-to-task framework via the user-driven Mission Area Planning process.

- Phase 2, **Program Development** – Formulates a portfolio of dollar constrained projects to meet customer-identified needs from Phase 1. The Technology Executive Officer (TEO), with the laboratories, develops a set of projects for those needs requiring development of new technology, while the Technology Transition Office (TTO) orchestrates development of a project portfolio for those needs which can be met by the



CTC	= Center Technology Council		TEO	= Technology Executive Officer	
MAT	= Mission Area Team		TTO	= Technology Transition Office	
MEB	= Mission Element Board		TPIPT	= Technical Planning IPTs	
EV	= Engineering Validation				

Figure 6.1: Technology Master Process

application/insertion of emerging or existing technology.

- Phase 3, **Program Approval** – Reviews the proposed project portfolio with the customer base via an Expanded S&T Mission Element Board and, later, the AFMC Corporate Board via S&T HORIZONs. The primary products of Phase 3 are recommended submissions to the POM/BES for S&T budget and for the various technology application/insertion program budgets.

- Phase 4, **Program Execution** – Executes the approved S&T program and technology application/insertion program within the constraints of the Congressional budget and budget direction from higher headquarters. The products of Phase 4 are validated technologies that satisfy customer weapon system and infrastructure deficiencies.

TMP IMPLEMENTATION STATUS

The Technology Master Process is in its first full year of implementation. AFMC formally initiated this process at the beginning of FY94 following a detailed process development phase. During the FY95 cycle, AFMC will use the TMP to guide the selection of specific technology projects to be included in the Science and Technology FY98 POM and related President's Budgets.

ADDITIONAL INFORMATION

Additional information on the Technology Master Process is available from HQ AFMC/STP, DSN 787-7850, (513) 257-7850.

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